WHOI-2011-04

Woods Hole Oceanographic Institution

Ocean Bottom Seismometer Augmentation of the Philippine Sea Experiment (OBSAPS) Cruise Report

by

Ralph Stephen[1], John Kemp[1], Sean McPeak[2], Tom Bolmer[1], Scott Carey[3], Ernie Aaron[3], Richard Campbell[4], Brianne Moskovitz[3], John Calderwood[3], Ben Cohen[3], Peter Worcester[3] and Matt Dzieciuch[3]

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Woods Hole Oceanographic Institution
Woods Hole, MA 02543

September 2011

Technical Report

Funding was provided by the Office of Naval Research under Contract Nos. N00014-10-1-0994 and N00014-10-1-0987.

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Approved for Distribution:

Maurice Tivey, Chair

Department of Geology and Geophysics

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August 31, 2011

Technical Report

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Abstract

The Ocean Bottom Seismometer Augmentation to the Philippine Sea Experiment (OBSAPS, April-May, 2011, R/V Revelle) addresses the coherence and depth dependence of deep-water ambient noise and signals. During the 2004 NPAL Experiment in the North Pacific Ocean, in addition to predicted ocean acoustic arrivals and deep shadow zone arrivals, we observed "deep seafloor arrivals" that were dominant on the seafloor Ocean Bottom Seismometer (OBS) (at about 5000m depth) but were absent or very weak on the Distributed Vertical Line Array (DVLA) (above 4250m depth). These "deep seafloor arrivals" (DSFA) are a new class of arrivals in ocean acoustics possibly associated with seafloor interface waves. The OBSAPS cruise had three major research goals: a) identification and analysis of DSFAs occurring at short (1/2CZ) ranges in the 50 to 400Hz band, b) analysis of deep sea ambient noise in the band 0.03 to 80Hz, and c) analysis of the frequency dependence of BR and SRBR paths as a function of frequency. On OBSAPS we deployed a fifteen element VLA from 12 to 852m above the seafloor, four short-period OBSs and two long-period OBSs and carried out an 11.5day transmission program using a J15-3 acoustic source.

Cruise Synopsis

Cruise: R/V Roger Revelle, RR1106

Departed: Kaohsiung, Taiwan, 1600L (0800Z) on April 29 (JD 119), 2011 (The ship sailed ten days later than planned because of engine trouble on the Revelle.)

Arrived Kaohsiung, Taiwan, 0800L (0000Z) on May 16 (JD136), 2011 (The cruise was six days shorter than planned.)

Science Party:

Ralph Stephen	WHOI	Chief Scientist
John Kemp	WHOI Mooring group	Deck operations
Sean McPeak	APL/UW	Source Controller and Monitor Engineer
Tom Bolmer	WHOI	Data Management and Watchstander
Scott Carey	SIO	Hydrophone Module Engineer
Ernie Aaron	SIO	OBSIP Engineer
Richard Campbell	OASIS Inc.	Visiting Scientist and Watchstander
Brianne Moskovitz	SIO Graduate Student	Watchstander
John Calderwood	SIO	Resident Technician
Ben Cohen	SIO	Computer Technician

Science Objectives:

1) Study the coherence and depth dependence of deep-water ambient noise and signals.
2) Study the relationship between seafloor pressure and seafloor particle motion for both ambient noise and short- and long-range signals.

Itinerary:

OBSAPS-DVLA, deployed on previous cruise, started recording at JD108/1607Z
Load Ship: JD 108 (18 April)
OBSAPS cruise departed Kaohsiung - JD119/0800Z (29 April, 1600L)
Arrive at DVLA site at JD120/2000Z (1 May, 0400L)
Start the transmission program at JD121/0200 (1 May, 1000L)
Transmission program with J-15's and deployments of XBTs and XSVs - 10 days
OBS Deployment and Survey - 1 day
End the transmission program at JD132/1200 (12 May, 2000L)
OBSAPS-DVLA, stopped recording JD132/1601Z (13 May, 0001L)
Recover six OBSs, the near-seafloor DVLA and four transponders - 2 days
Depart DVLA site at JD134/1300Z (14 May, 2100L)
Arrive Kaohsiung at JD136/0000Z (16 May, 0800L)
Unload ship: May 16

Table of Contents

Figures

Tables

Appendices

1. Introduction

This project addresses the coherence and depth dependence of deep-water ambient noise and signals. Seafloor signals will be studied in the band from 50-400Hz and seafloor ambient noise will be studied in the band from 0.03 - 80Hz. We were originally awarded 28 days of ship time on the R/V Revelle to carry out a Deep DVLA and OBS program in the Philippine Sea immediately after the recovery of the full water-column PhilSea10 DVLA in March-April 2011. Two days were for an extension to the previously funded DVLA Recovery Cruise. In this extension the Deep DVLA (Distributed Vertical Line Array) was deployed. Twenty-six days were awarded for the OBSAPS cruise, which occurred immediately after the DVLA Recovery Cruise. Due to engine failure on the Revelle the OBSAPS cruise was delayed ten days and shortened by six days. The cruise dates, excluding a loading day at the beginning, were April 29 to May 16, 2011. This cruise deployed 6 OBSs (Ocean Bottom Seismometers) and carried out a source program using a J15-3. The OBSs and OBSAPS (Deep) DVLA were recovered at the end of this cruise.

2. Scientific Objectives

On NPAL04 we observed a new class of arrivals in long-range ocean acoustic propagation that we call Deep Seafloor Arrivals (DSFAs) because they are the dominant arrivals on ocean bottom seismometers (Stephen *et al.*, 2008; Mercer *et al.*, 2009; Stephen *et al.*, 2009). They either were undetected or very weak on the deepest DVLA hydrophone located near the conjugate depth about 750m above the seafloor. It appears that at least part of the path for DSFAs is through or on the seafloor perhaps as an interface wave (Figures 1 and 2). We wanted to do a similar experiment in the Philippine Sea (Figures 3 and 4) to learn more about this class of arrival.

The long-term objective here is to understand the relationship between seafloor pressure and seafloor particle motion for both ambient noise and short- and long-range signals. What is the relationship between the seismic (ground motion) noise on the seafloor and the acoustic noise in the water column? What governs the trade-offs in contributions from local and distant storms and in contributions from local and distant shipping? How effective is seafloor bathymetry at stripping distant shipping noise from the ambient noise field?

This project will quantitatively compare the signal and noise levels in the Philippine Sea in the 50- 400Hz band on the hydrophones and geophones at the seafloor to the hydrophones suspended up to 1 kilometer above the seafloor, for ranges from near zero to 250km. We will also study seafloor ambient noise in the Philippine Sea in the band from 0.03 - 80Hz and compare it to other deep-water sites in the Pacific Ocean. Specific questions to be addressed include: i) Is there evidence for Deep Seafloor Arrivals in the Philippine Sea (water depths around 5500m) that are similar to the ones observed on NPAL04 (water depths around 5000m)? ii) What is the frequency dependence of the deep arrival structure from 50 - 400Hz? iii) What is the range dependence of the deep arrival structure out to 250km? iv) What is the azimuth dependence of the deep arrival structure? v) What are the relative SNRs of arrivals on vertical

and horizontal geophones, co-located seafloor hydrophones and moored hydrophones (from 20m to 1000m off the bottom - 15 hydrophones at about 60m separation)? vi) What are the phase relationships between pressure and vertical and horizontal particle motion for deep seafloor arrivals and ambient noise? vii) What is the relationship between the observed deep arrival structure and the PE predicted arrival structure? viii) How far above the seafloor does the Deep Seafloor Arrival structure extend?

3. Technical Approach

Originally the OBSAPS DVLA (O-DVLA) was to be deployed at the location of the PhilSea10 DVLA, following its recovery. Because of fouling problems at this site, the OBSAPS site was moved about 8.7km to the southwest: Lat: 21deg 19.559'N Lon: 125deg 56.325'E. The goal was to use the existing DVLA acoustic transponder net, which would not be recovered until after the OBS experiment. The O-DVLA consisted of one 1000-m DVLA section, with a D-STAR at the top. The O-DVLA consisted of 15 hydrophone modules from 12m above the seafloor to near the conjugate depth. A current meter was deployed at the bottom of the DVLA.

Each OBS had a three-component seismometer and hydrophone or differential pressure gauge. Four OBSs were L-CHEAPOS sampling at 1000sps suitable for the frequency band from 1-400Hz, and two OBSs were broadband instruments sampling at 200sps and suitable for the frequency band from 0.03 to 80Hz. The L-CHEAPO short period OBSs are pretty much the same units we had in 2004. Some critical differences are that the 2011 OBSs acquired three components of particle motion plus acoustic pressure and they sampled at 1000sps. (The 2004 OBSs had only a vertical geophone and hydrophone and sampled at 500sps.) We do not expect that the system noise levels for the geophone or hydrophone channels will be significantly different from the 2004 experiment which was system noise limited (Stephen *et al.*, 2008). The broadband OBSs will provide seafloor ambient noise data for comparison with other deep-water, broadband data sets in the Pacific such as the Hawaii-2 Observatory (H2O) (Duennebier *et al.*, 2002; Stephen *et al.*, 2006) and the Ocean Seismic Network Pilot Experiment (OSNPE) (Stephen *et al.*, 2003).

The source program was carried out using a J15-3 with a bandwidth from 50 to 400Hz, depths down to 100m, ranges to 250km and a variety of azimuths based on the known bathymetry. The main format of the transmission program was binary maximal-length sequences (m-sequences). The receptions can be time compressed using matched field processing to yield impulsive arrivals, that can be studied for multi-path effects and signal-to-noise ratios. For at least one azimuth we had no bathymetric blockage along a line out to 250km, similar to NPAL04, where we can look for DSFA's in a clean wave guide. At least one other path will had bathymetric blockage for comparison. Many radial lines and a "Star of David" at one CZ range were shot to study the range and azimuth dependence of the bottom interaction within one CZ. We also stayed at fixed locations for durations up to four hours to study the temporal variability of the arrival structure and to permit stacking to improve signal-to-noise ratios.

For background information two PE TL computations are shown in Figure 4. The strongest arrivals for near seafloor receivers occur at 1/2CZ, 3/2CZ, and 5/2CZ ranges, that is 30, 90, 150km. Strong water multiples (bottom bounce paths) occur for ranges less than 90km. DSFAs could occur at ranges between the 1/2CZ's. The locations of the PhilSea10 pentagon and of the OBSAPS Deep DVLA within the Western Pacific are shown in Figure 5.

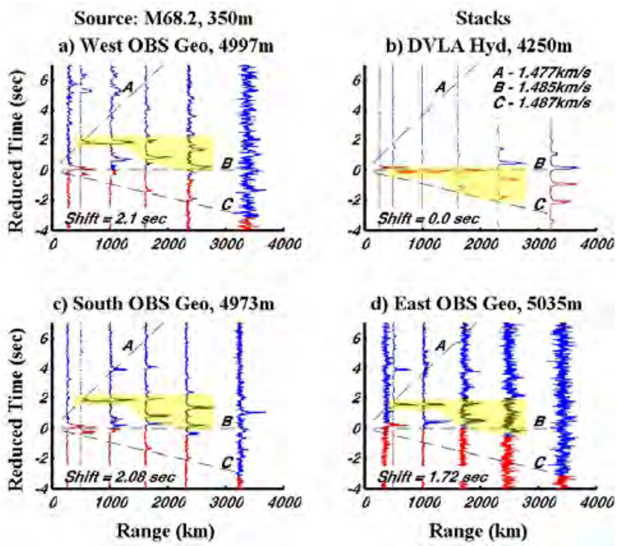


Figure 1 DSFA Summary

The seafloor arrivals shown in the highlighted yellow regions have a distinctive pattern for all three OBSs deployed on NPAL04. The arrival pattern appears to be a delayed version, by about 2sec, of the pattern on the deepest element of the DVLA. The shifts of these arrivals with respect to the PE arrivals on the DVLA are a constant regardless of range.

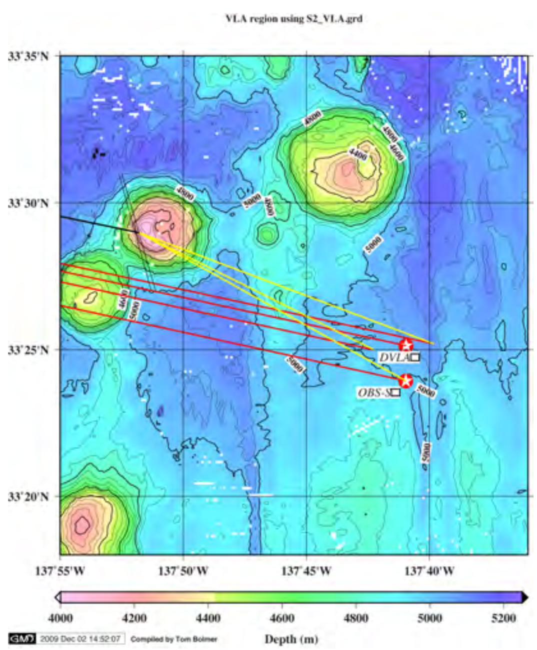


Figure 2 NPAL Bathymetry

The deep seafloor arrival pattern highlighted in yellow in Figure 1 is consistent with the following propagation path. From all sources from T500 toT2300 the sound travels through the sound channel to seamount B (black line). The sound is then coherently scattered from seamount B and travels to the OBSs as Scholte waves trapped at the seafloor (yellow lines). Paths from the sources directly to the DVLA and OBSs are also shown (red lines).

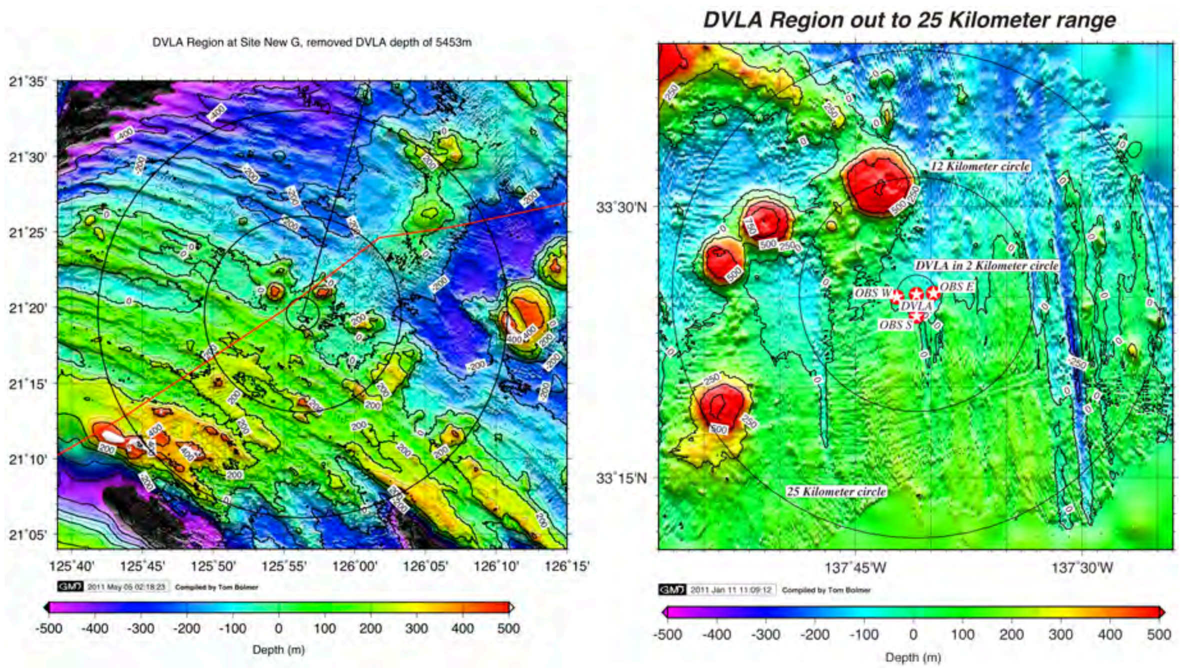


Figure 3a Comparison of Relief - OBSAPS vs NPAL04

The relief at the OBSAPS site (top) and the NPAL04 site (bottom) are compared. Both plots show the relief relative to the water depth at the DVLA site with the same color scheme. The three circles in each figure are at 2, 12 and 25km radii. Some of the DFSAs on NPAL04 appear to be excited at the third seamount from the bottom (see Figure 2). There are similar features at similar ranges from the DVLA at the OBSAPS site. The DVLA depth at NPAL04 was about 5000m and at OBSAPS was about 5500m. The conjugate depths at the two sites were about 4250m and 4850m (May in the WOA, 4784m from CTDs during the cruise) respectively. So the relationships between conjugate depth, DVLA depth and feature relief are comparable at the two sites. Will DSFAs be excited at the OBSAPS features as well?

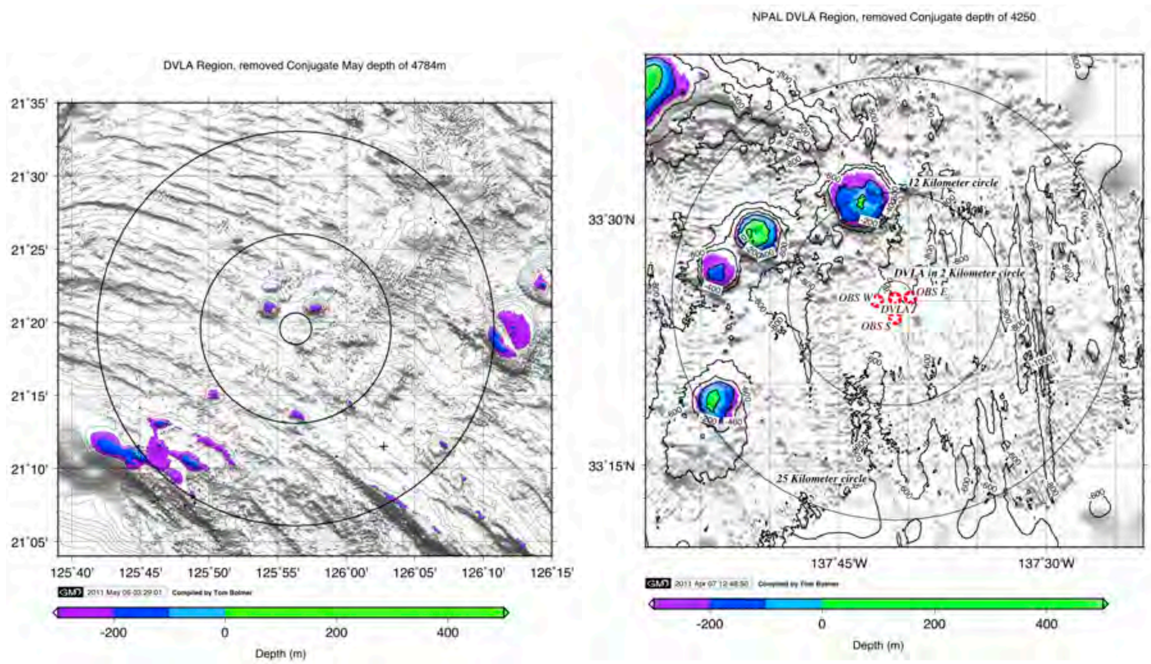
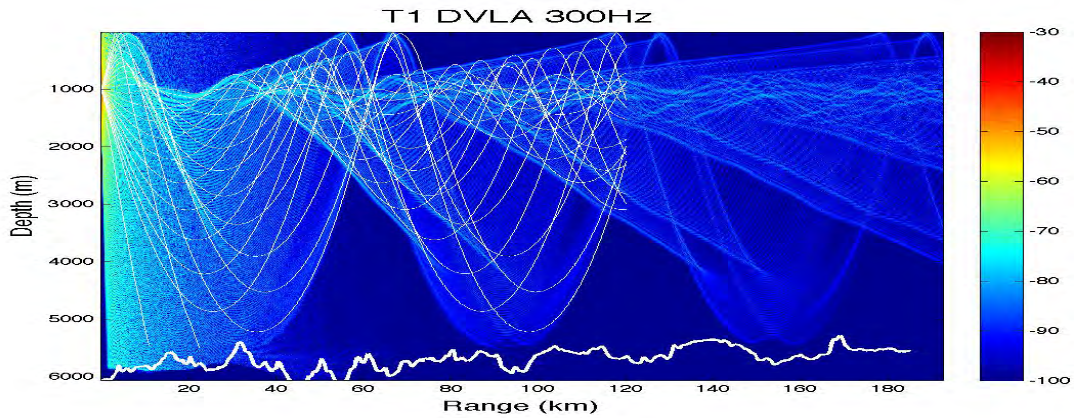


Figure 3b Depth below Conjugate Depth - OBSAPS vs NPAL04

The conjugate depths at the two sites were about 4250m and 4784m respectively. These figures compare the seafloor depth relative to the conjugate depth at the two sites. Although there are no features above the conjugate depth at the OBSAPS site it is possible that the Airy phase of long range guided waves will tunnel energy into the seafloor. Of course these features will be excited by direct and bottom bounce paths at short ranges (less than 35km or so). The relationships between conjugate depth, DVLA depth and feature relief are comparable at the two sites. Will DSFAs be excited at the OBSAPS features as well?

TL (PE with overlayed rays) for axial source (about 1000m):



TL (PE) for shallow (100m) source:

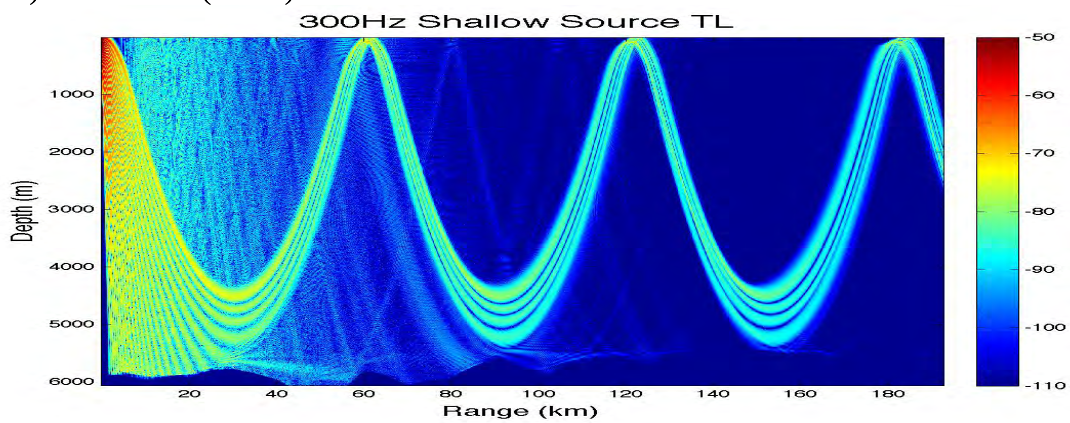


Figure 4 Example of Transmission Loss Curves

Transmission loss curves at 300Hz for a representative Philippine Sea sound speed structure (from the PhilSea10_MOPS_TestPlan_July4.docx, Kevin Heaney, pers. comm.) and 100m source depth. These show the 1/2CZ convergent zone structure for near-bottom receivers (that is at 30, 90 and 150km).

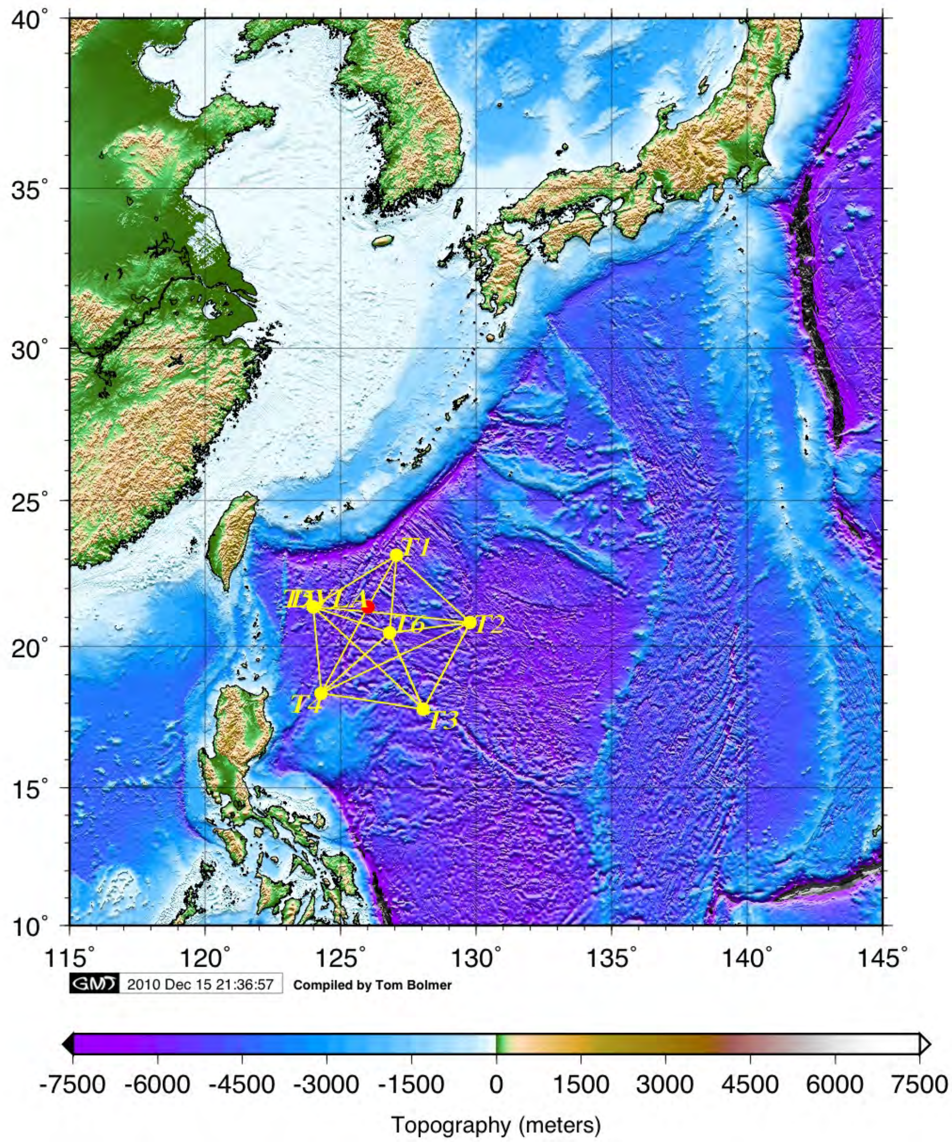


Figure 5 PhilSea10 Pentagon and OBSAPS Location Diagram
Location diagram of the PhilSea10 and OBSAPS experiments. The red dot is the location of the DVLA (on PhilSea10) and the O-DVLA (OBSAPS - DVLA).

4. OBSAPS Experiment Geometry and Schedule

The scientific objectives of the cruise are 1) to study the coherence and depth dependence of deep-water ambient noise and signals, and 2) to study the relationship between seafloor pressure and seafloor particle motion for both ambient noise and short- and long-range signals. Our experience on NPAL04 indicated that the behavior of sound and vibration at the seafloor can be quite different from the sound 100's of meters above the seafloor and can be strongly dependent on bathymetric relief. Since the physical mechanisms that control sound and vibration at the seafloor are still uncertain, particularly for Deep Seafloor Arrivals, a comprehensive areal survey is warranted. Figure 6 shows the eight radial lines out to 100km superimposed on the bathymetry and Figure 7 shows the bathymetry along those radial lines. This pattern forms the basis for the transmission program.

A summary of the principal equipment that was deployed on OBSAPS with estimated data sizes is given in Table 1 and ancillary measurements are given in Table 2. The source was a J15-3 (and we took along a back-up unit). The principal receivers were 15 hydrophone elements on the OBSAPS DVLA, four L-CHEAPO short period seismometers, two broadband seismometers, a current meter on the OBSAPS DVLA, and a monitor hydrophone and depth (pressure) sensors on the J15-3. Each seismometer has a three-component inertial sensor (a short period 4.5Hz geophone or a long period Trillium 240) plus an acoustic pressure sensor (a short period hydrophone or differential pressure gauge). Three of the short period OBSs also had an external, autonomously recording hydrophone module identical to the hydrophone modules on the DVLA. Figure 8 shows the locations of the six OBSs with respect to the DVLA. Figure 9 shows the DVLA mooring schematic with the depths of the hydrophones. Figure 10 compares the nominal depths of the hydrophones on OBSAPS with PhilSea09 and PhilSea10.

A timeline for all of the cruise activities is given in Table 3. The locations for the transmission "events" are shown in Figure 11 and the schedule of events is given in Table 4. The J15-3 transmission program, originally scheduled for 14-days, took 11days 15.5hours including 8hours waiting-on-weather. The way-points and instrument locations are given in Table 5. A note on depths is given in Section 5.

5. Note on Depths

This note attempts to clarify various "depths" of seafloor equipment used in the experiment. The relevant equipment consists of the anchor of the O-DVLA (hydrophone module depths above this are given in the array design), six OBSs and four transponders.

Depth was determined in two ways: from multi-beam data of various types and from the acoustic surveying (tri-lateralization?) of the O-DVLA and transponders. The ship provides a "multi-beam depth" giving the depth below the ship in real-time from the multi-beam system. For example, this depth is used for the OBS drop locations and OBS location surveys. Ideally

the shipboard real-time multi-beam has been calibrated and updated using recent CTD and XBT data. Multi-beam bathymetric maps are constructed by combining data from as many available tracks on as many available cruises as possible. This data needs to be edited for "glitches" and "drop-outs" which is done in person and may vary from interpreter to interpreter. Depth from multi-beam bathymetry also depends on the resolution of the averaging and interpolation which will also vary from interpreter to interpreter.

Prior to the cruise a number of site and depth scenarios were discussed, so it is important to keep track of when a particular "depth number" is used. The OBSAPS DVLA (O-DVLA) was eventually deployed at Site G. Some figures and text may still refer to Site G and O-DVLA is sometimes referred to as the Deep DVLA. Even on the cruise and for a single instrument, there are depths for "planned locations", "drop locations" and "final navigated seafloor locations". For example, Table 6 shows planned, drop and final depths for the six OBSs. All of these depths are estimated from the multi-beam (125m grid size) bathymetry, prepared by Tom Bolmer (as of May 10, 2011), for the given OBS locations (file: OBS_location_summary_STB_5-10-11.docx).

The depth for the O-DVLA in the same terms as Table 6 was 5433m, 5m shallower than the depth, 5438.1m, given in the location table from the previous cruise (Table 7, file: Peters_locations_Site_G.pdf). The multi-beam depth in this table was 5446m, but it is not clear what the basis for this multi-beam number is. We believe that the depths in Table 7 (dep) were determined from the acoustic "tri-lateralization" survey carried out on the previous cruise. For better or worse we use this depth for the O-DVLA as the reference for "nominal depths" for the other instruments. For example, to get nominal depths for the OBSs we take the depths from the bottom of Table 6, round to the nearest meter and add five meters. A discussion of how the multi-beam data was processed and information on improved depths is given in Appendix 6.

Note that for locating the OBSs, the OBSIP group uses the multi-beam depth from the ship at the drop location. They do not compute depth in the survey procedure. Depths in the OBS navigation files will only agree approximately with the depths in Table 6.

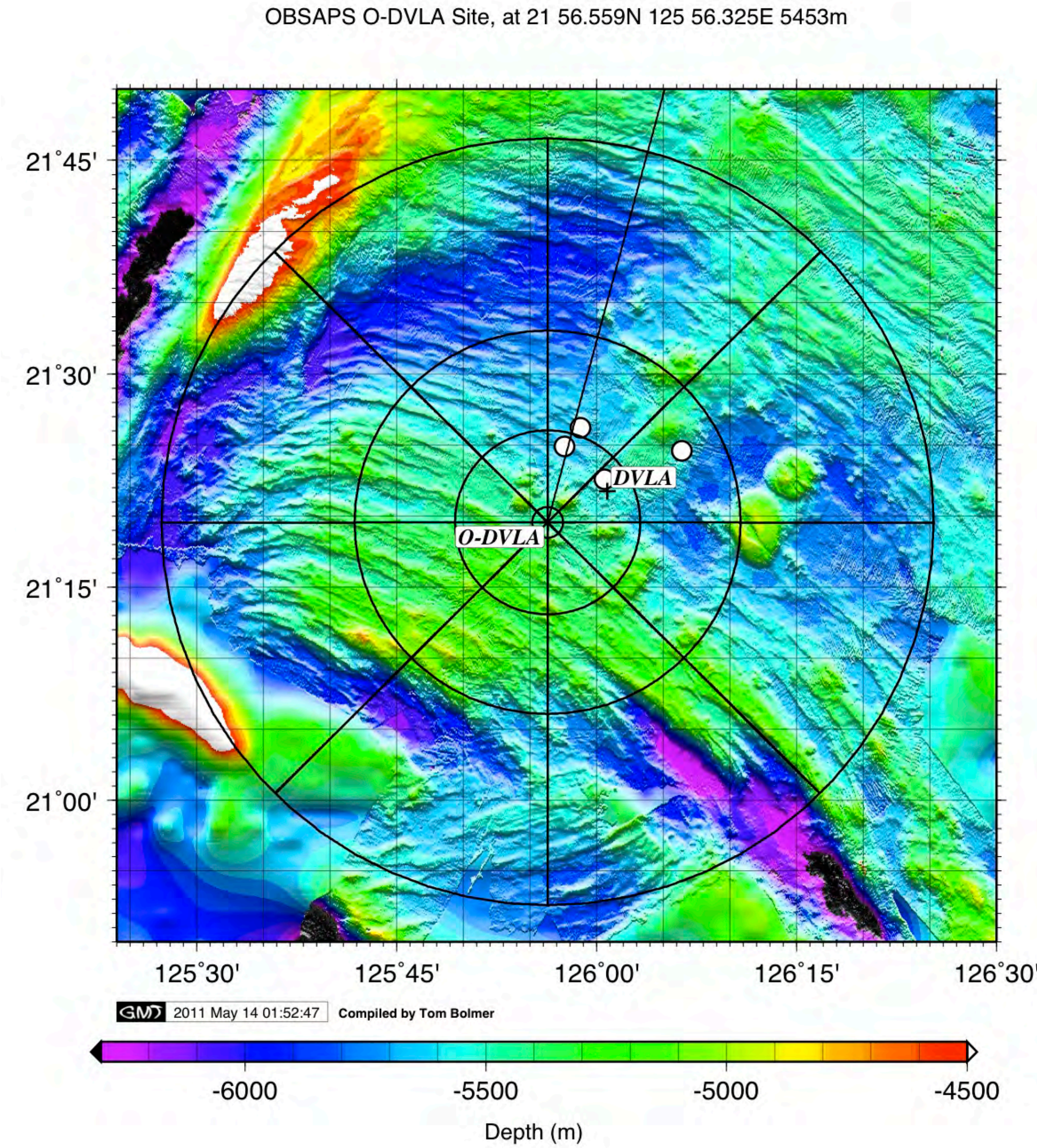


Figure 6 DVLA and O-DVLA on 50km Scale

The OBSAPS DVLA (O-DVLA) was located about 10km southwest of the PhilSea10 DVLA. The mooring locations that fouled with the PhilSea10 gear are shown as white circles. Eight radial lines out to 50km, equally spaced in azimuth and starting from North form the basis for the OBSAPS transmission program. The circles have radii of 2km, 12km, 25km and 50km radius. The bathymetry along these lines is shown in Figure 7. We also transmitted on one 250km line at N15degE.

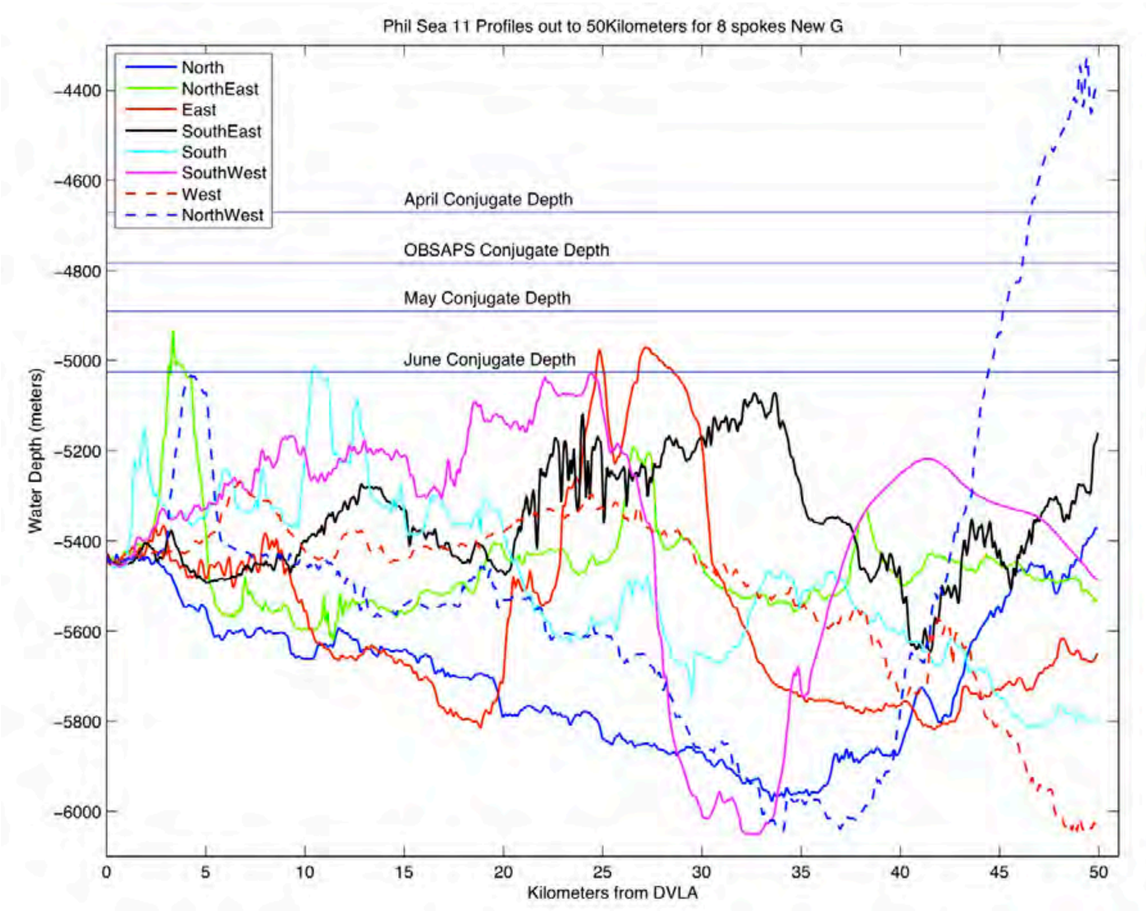


Figure 7 Radial Profiles

Bathymetry along the eight radial lines shown in Figure 6. Also shown are the conjugate depths for April, May and June based on World Ocean Atlas data (from Worcester's PhilSea10 Cruise Plan) and the conjugate depth based on sound speed profiles acquired during OBSAPS. All of the bathymetry within 40km of the O-DVLA is below the OBSAPS conjugate depth. For short range transmissions (<1/2CZ) bathymetric highs will still be insonified by direct paths and bottom bounce paths. At long ranges (>5/2CZ) the bathymetric highs could be insonified by tunneling of energy below the turning points of the guided waves. See Figure 4.

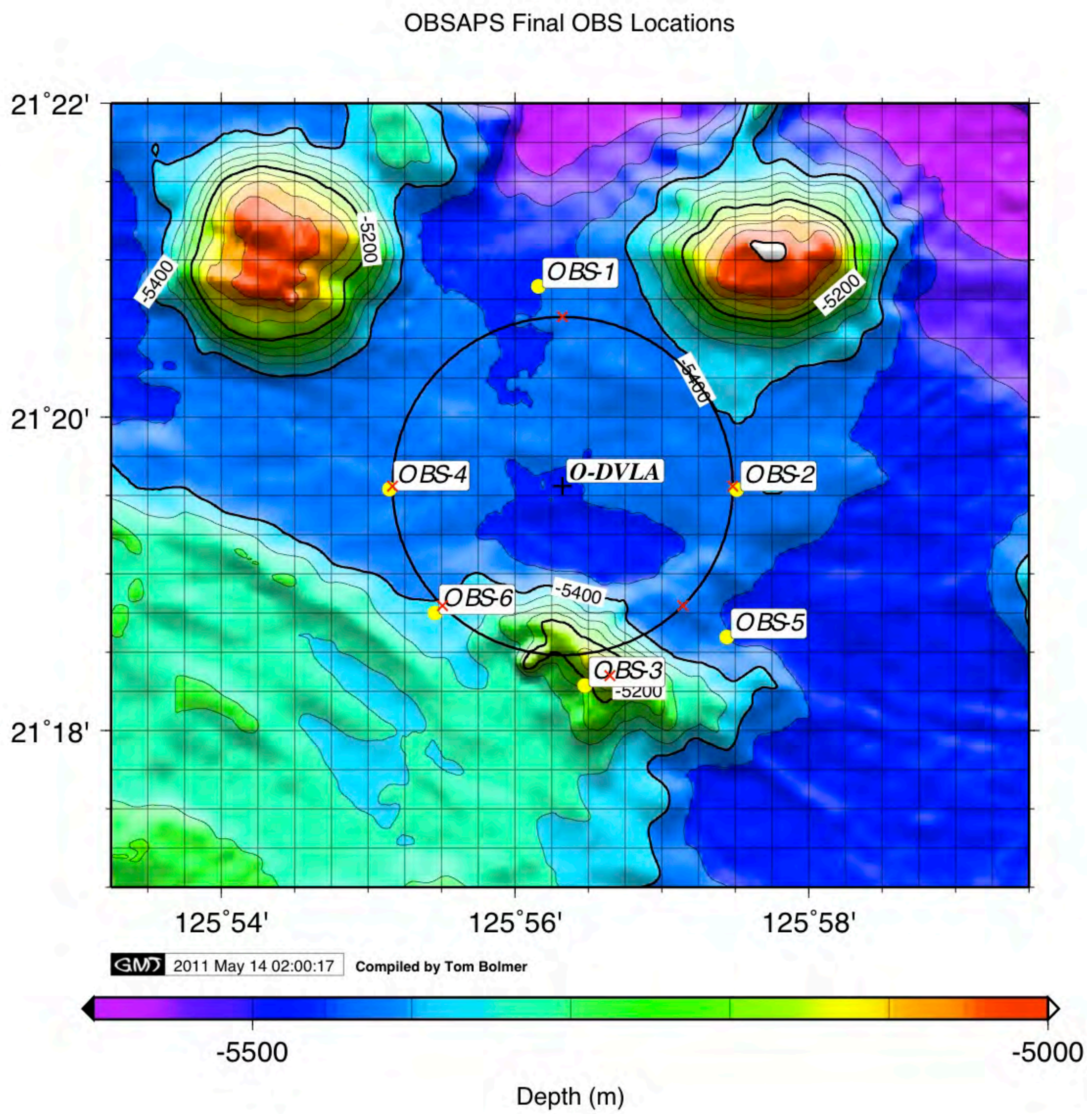


Figure 8 OBS Locations on 2km Scale

Yellow dots indicate the locations of the four L-CHEAPO OBSs (#1-4) and two broadband OBSs (#5-6) with respect to the O-DVLA location. (Red x's are the drop locations.) All OBSs are at least two kilometers from the O-DVLA. The O-DVLA is located in a shallow depression. The southern OBS (#3) was dropped at the top of the small seamount but drifted to the southern side while descending. OBSs #1-3 each had an exterior hydrophone module attached. OBS#2 flooded and provided no data.

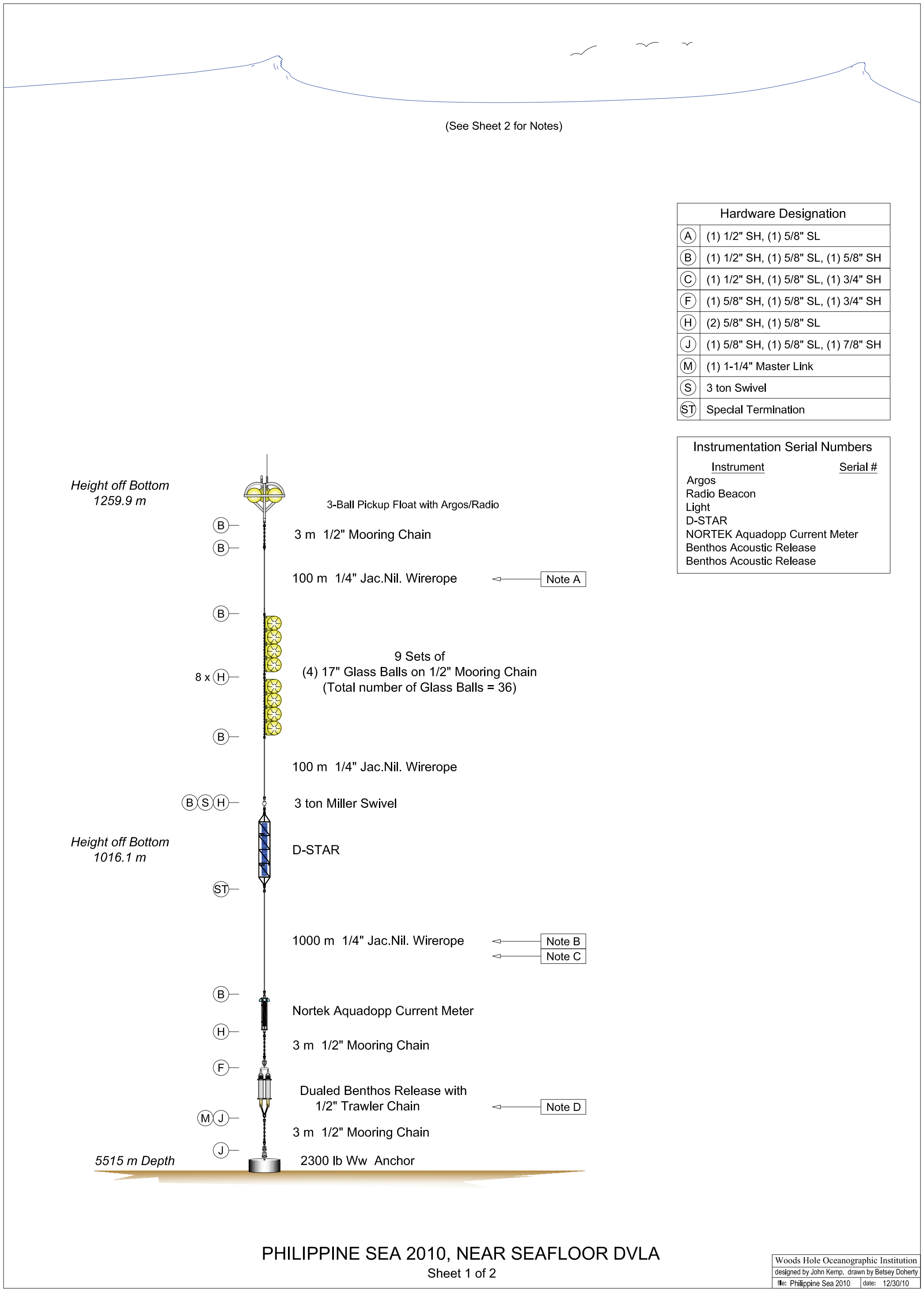


Figure 9a Schematic of the OBSAPS DVLA Mooring
Schematic of the OBSAPS DVLA mooring geometry.

Hardware Required (Per Mooring Without Spares)	
Qty	
6	1/2" Anchor Shackles (SH)
29	5/8" Anchor Shackles
1	3/4" Anchor Shackles
2	7/8" Anchor Shackles
19	5/8" Sling Links (SL)
1	1 -1/4 Master Link
1	3 ton Swivel with Anode

Spares Required	
Qty	
1	Set of spares below the release
1	Spare Anchor
10	1/2" Anchor Shackles
20%	Spares on Remaining Hardware

Note A

Spare and adjustable shots of wire from the Philippine Sea 2010 Experiment can be used.

Note B

Measure cable back from lower standard swage of 1/4" wire for mounting hydrophone modules.

Label as Follows:	Mount	Serial #
at 1.0 m - Label 5503 m	H14	
at 11.0 m - Label 5493 m	H13	
at 21.0 m - Label 5483 m	H12	
at 31.0 m - Label 5473 m	H11	
at 41.0 m - Label 5463 m	H10	
at 51.0 m - Label 5453 m	H9	
at 61.0 m - Label 5443 m	H8	
at 71.0 m - Label 5433 m	H7	
at 121.0 m - Label 5383 m	H6	
at 241.0 m - Label 5263 m	H5	
at 361.0 m - Label 5143 m	H4	
at 481.0 m - Label 5023 m	H3	
at 601.0 m - Label 4903 m	H2	
at 721.0 m - Label 4783 m	H1	
at 841.0 m - Label 4663 m	H0	

Note C

Mooring will be deployed using a SIO Traction Winch

Note D

WHOI supplied Dualing Chain

PHILIPPINE SEA 2010, NEAR SEAFLOOR DVLA
Sheet 2

Figure 9b OBSAPS DVLA Mooring Geometry and Hydrophone Depths
Supporting notes for the mooring geometry in Figure 9a. Note B gives the nominal depths of the 15 hydrophone channels assuming that the seafloor depth is 5515m. The accepted nominal depth for the actual OBSAPS DVLA deployment is 5438m. All of the hydrophone modules including the three on the short-period OBSs returned useful data except hydrophone module number H9.

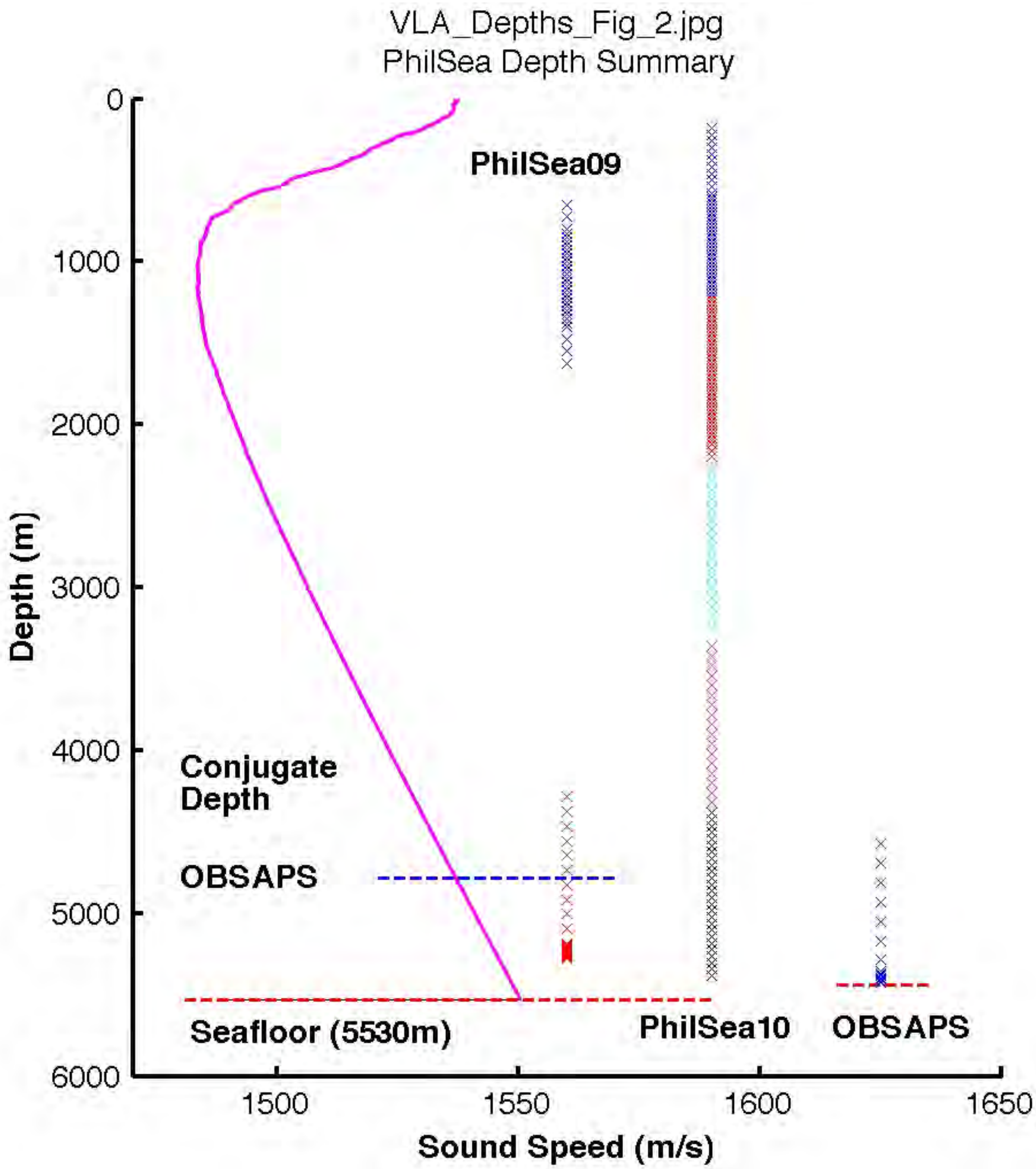


Figure 10a PhilSea09, PhilSea10 and OBSAPS Array Summary (full water depth)
Summary of hydrophone module locations over the whole water column on PhilSea09, PhilSea10, and OBSAPS. The goal of OBSAPS is to study near-bottom, deep-water ambient noise and signal propagation.

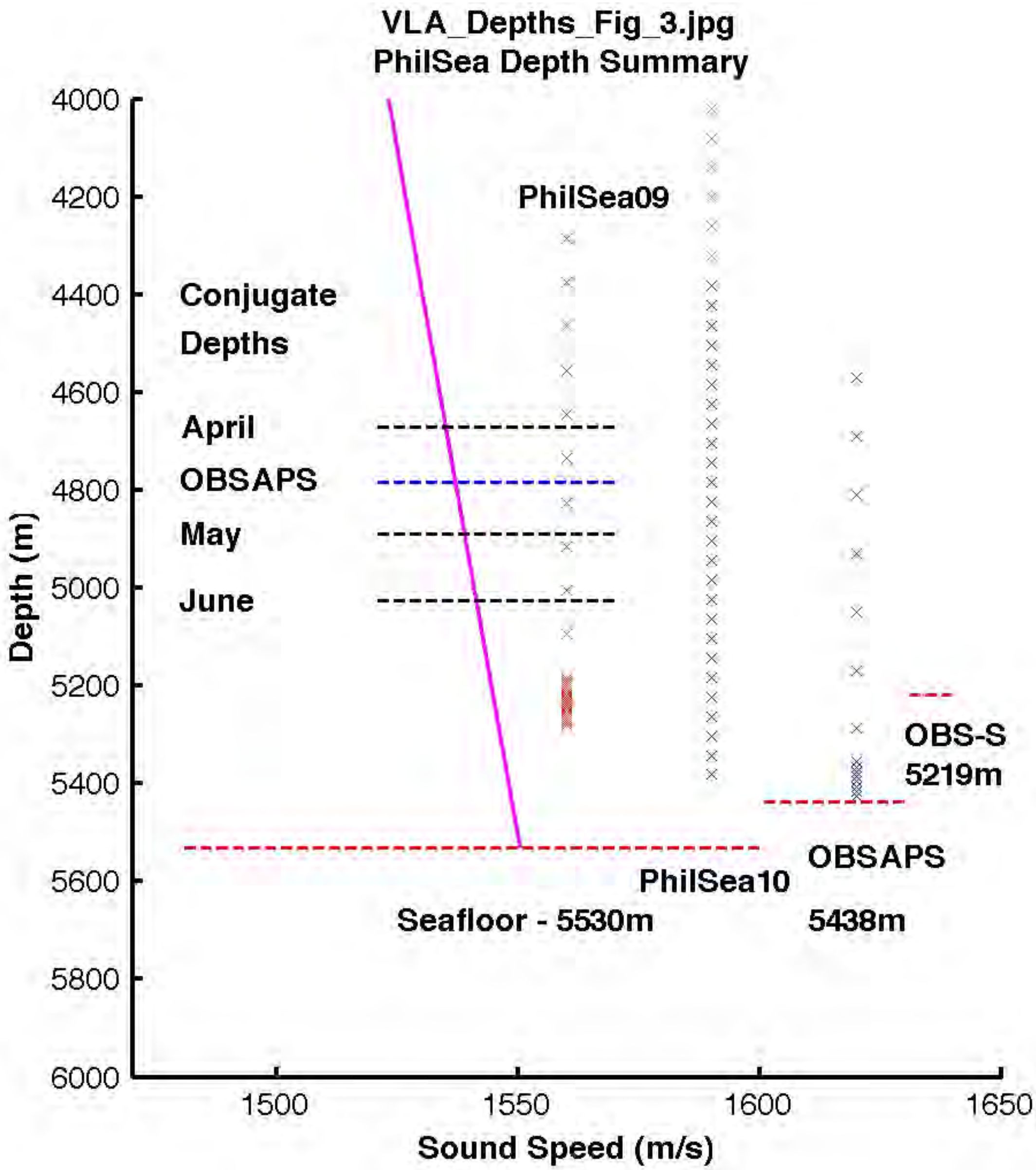


Figure 10b PhilSea09, PhilSea10 and OBSAPS Array Summary (bottom 1500m)
Summary of hydrophone module locations within 1500m of the seafloor on PhilSea09, PhilSea10, and OBSAPS. The relocated OBSAPS site is 92m shallower than the original DVLA sites. The South OBS was dropped on a seamount with a target depth of 5073m (345m above the O-DVLA anchor), but it landed on the side of the seamount at 5219m (219m above the O-DVLA anchor). The depths of the other OBSs are within 40m of the O-DVLA anchor depth.

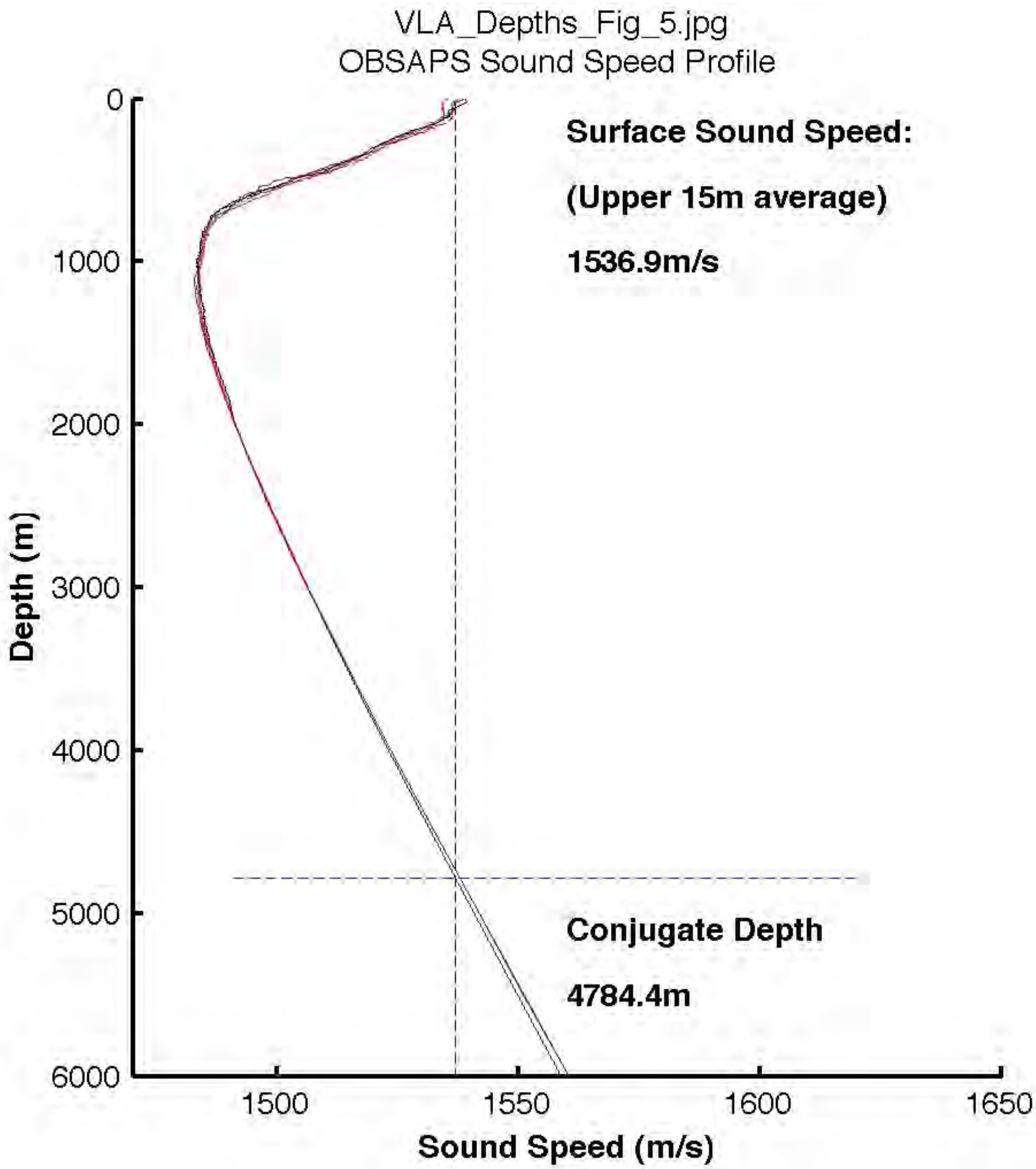


Figure 10c OBSAPS Conjugate Depth Summary
The conjugate depth at the OBSAPS site during the OBSAPS experiment, based on XBTs and CTDs taken during the experiment, was 4784m.

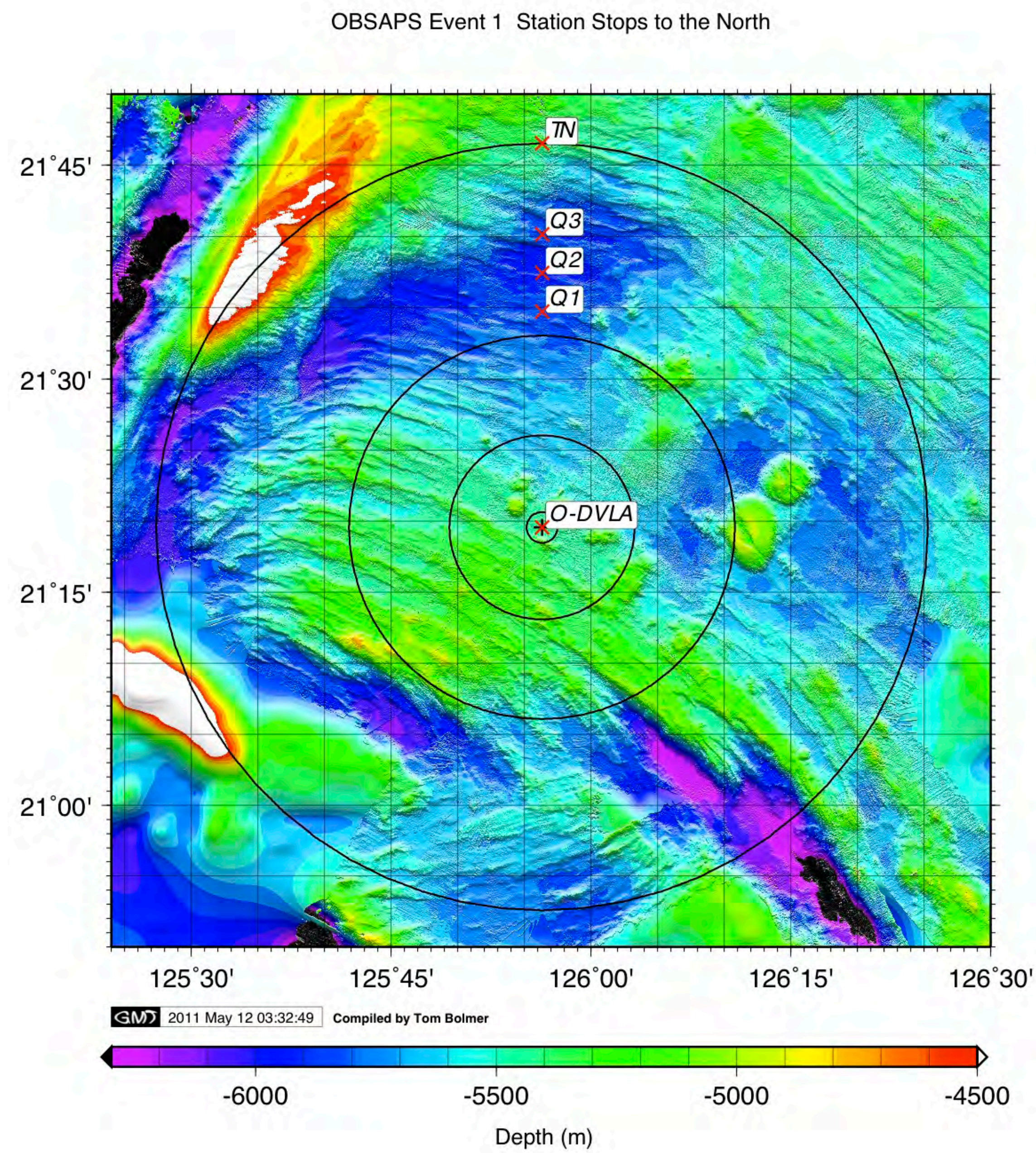


Figure 11a OBSAPS Event 1 Locations

Locations for Event #1, 1/2CZ station stops to the North (Q1, Q2, Q3 with Multi-Frequency Station Stop M-sequences), overlain on bathymetry. The fixed stations are separated by 5km at roughly 1/2 CZ from the DVLA. Circles have radii of 2, 12, 25, and 50km.

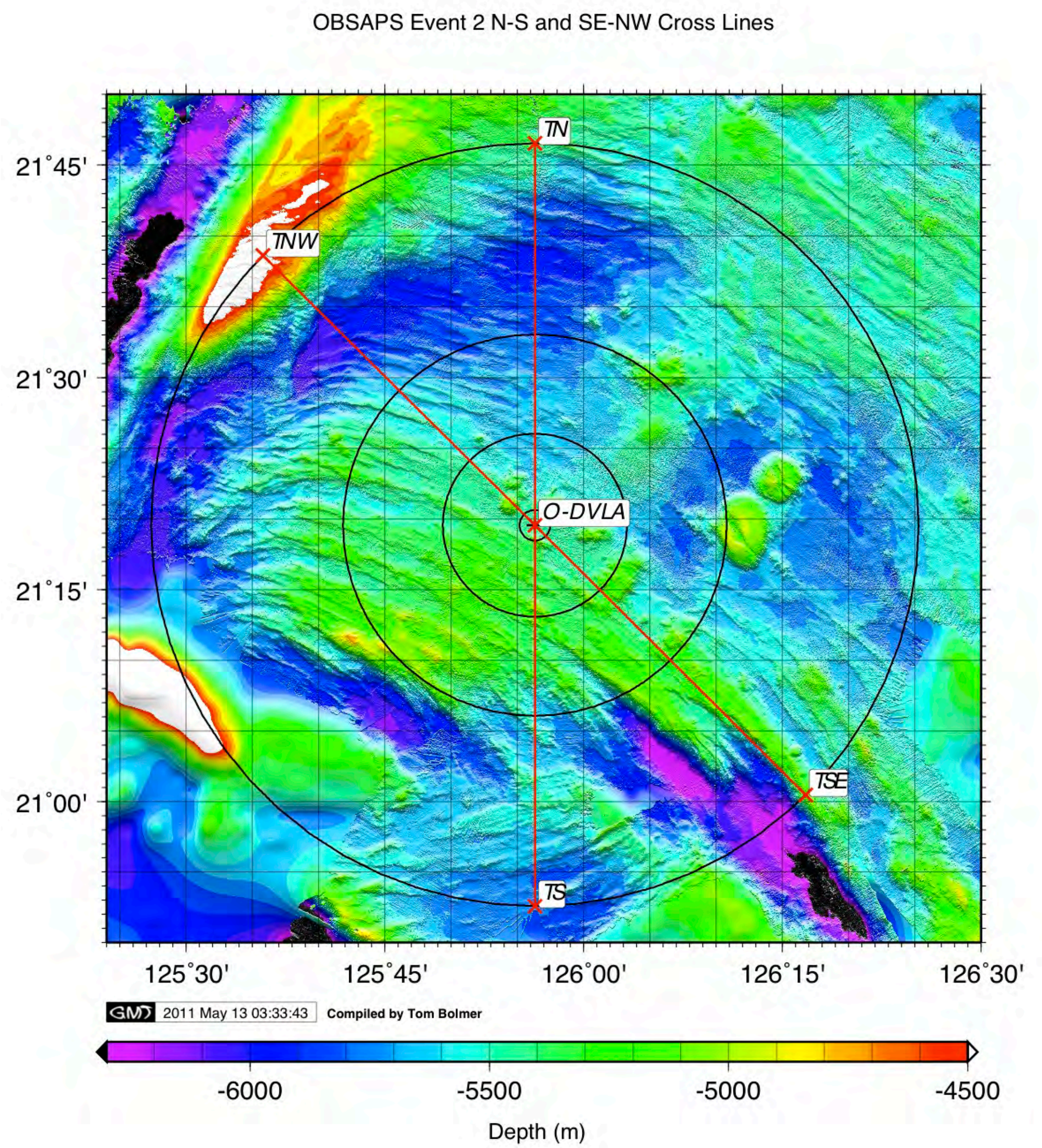


Figure 11b OBSAPS Event 2 Locations
Locations for Event #2, 50km Radials (at 2 knots using Short Range, Multi-Frequency M-sequences), North to South and Southwest to Northeast overlain on bathymetry.

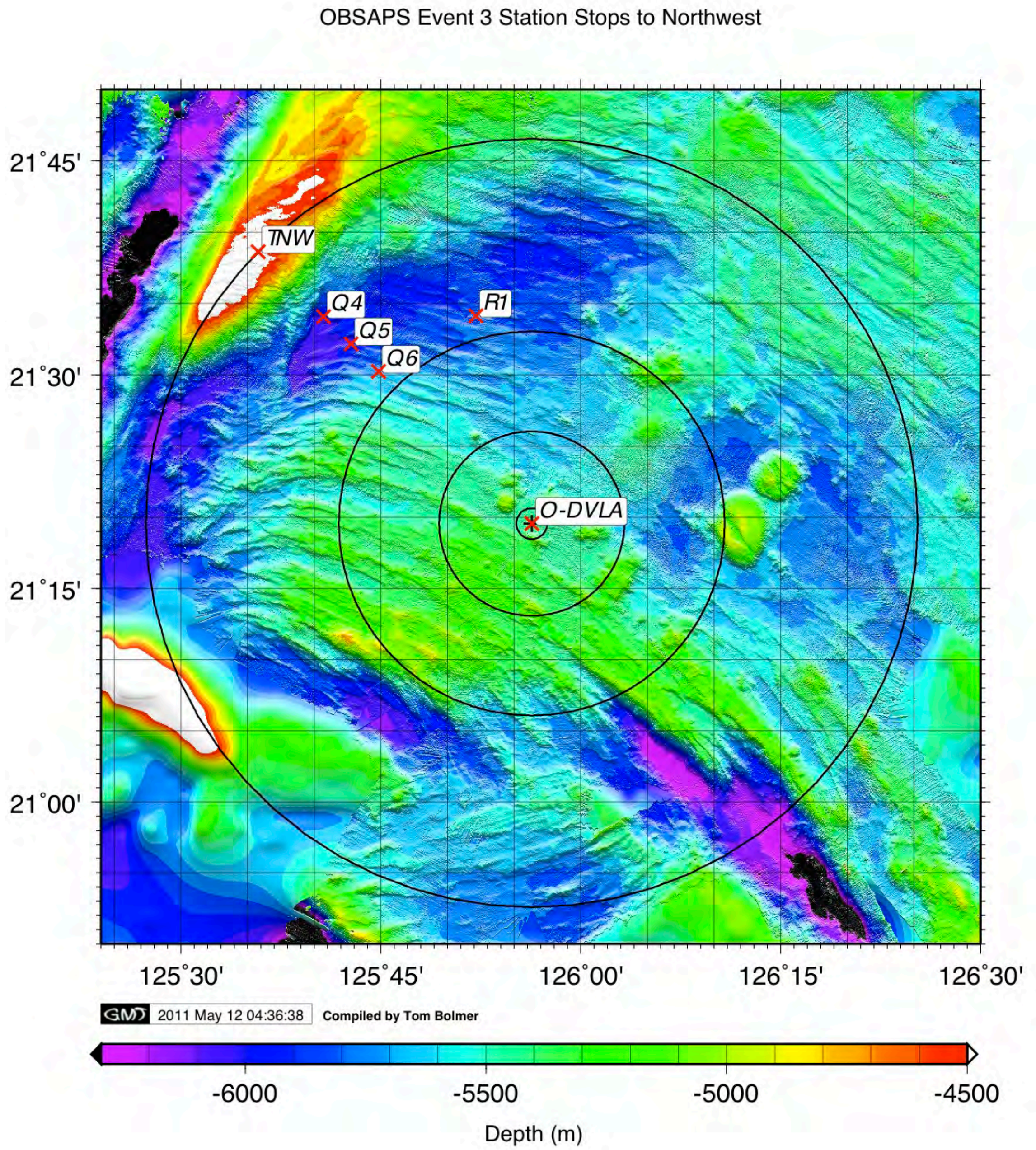


Figure 11c OBSAPS Event 3 Locations
Locations for Event #3, 1/2CZ station stops to the Northwest (Q4, Q5, Q6 with Multi-Frequency Station Stop M-sequences), overlain on bathymetry. The fixed stations are separated by 5km at roughly 1/2 CZ from the DVLA.

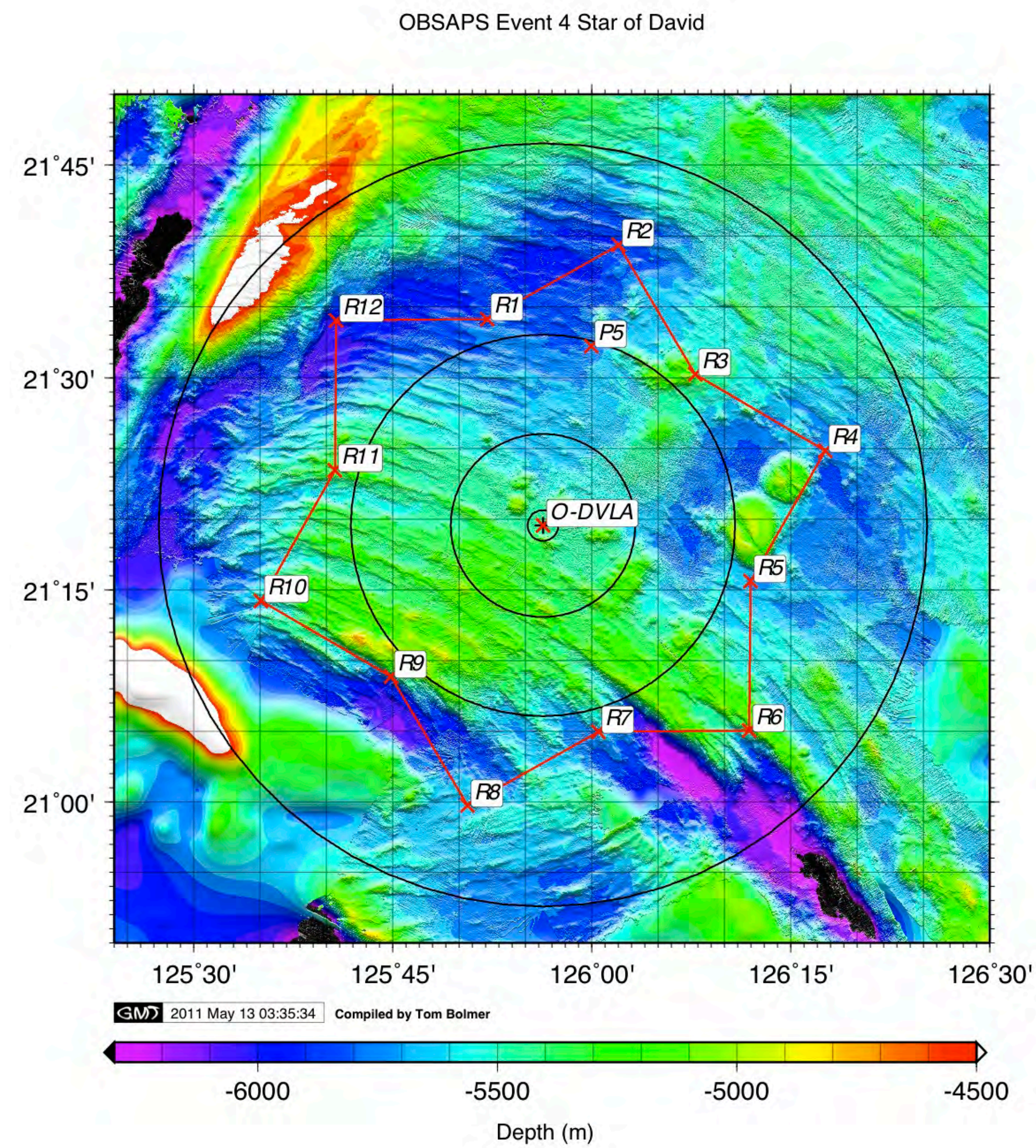


Figure 11d OBSAPS Event 4 Locations
Locations for Event #4, Star of David (at 2 knots using Short Range, Multi-Frequency Transmissions), overlain on bathymetry. This pattern is the same pattern that Kevin Heaney used on the July 2010 PhilSea cruise.

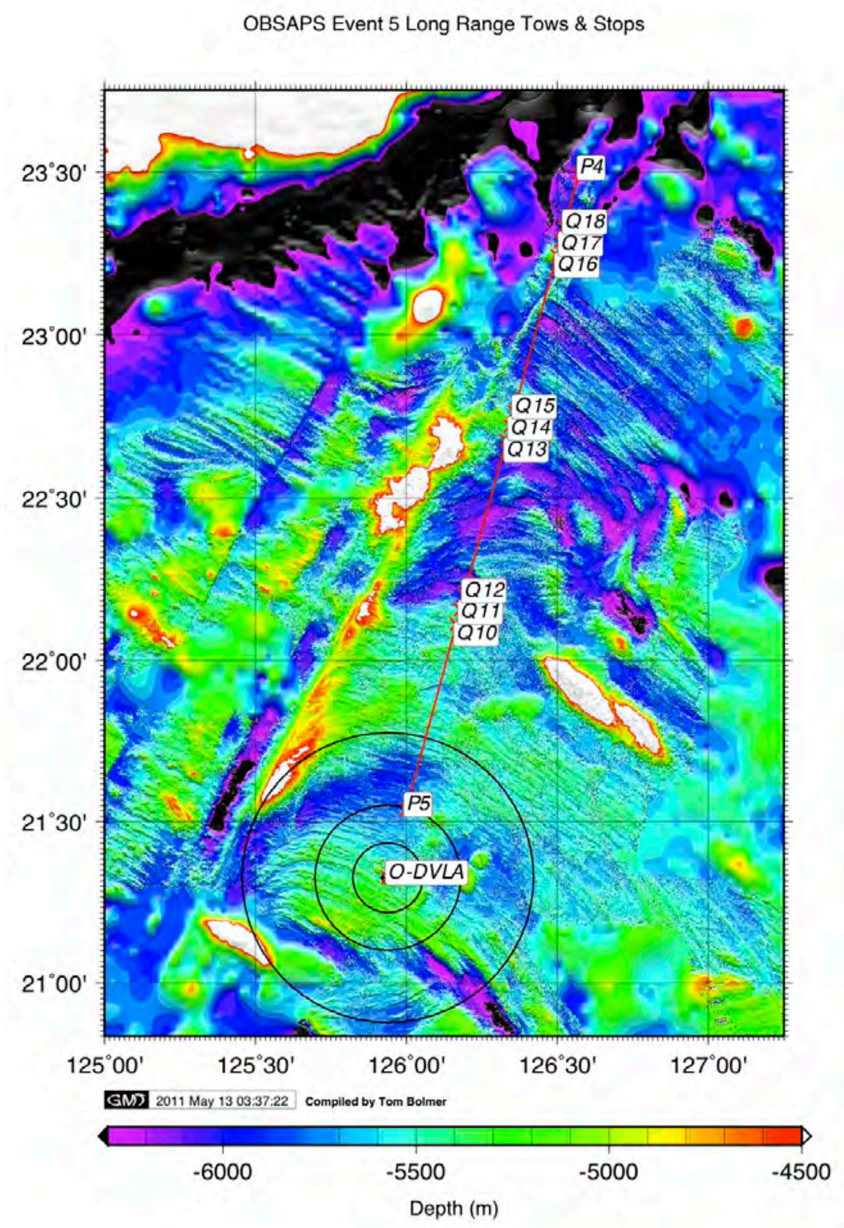


Figure 11e OBSAPS Event 5 Locations

Locations for Event #5, 250km Long Line, are overlain on the bathymetry. The azimuth is N15degE and is roughly parallel to the DVLA to T1 line on Phil Sea '10, but this line does not terminate at T1. We transmitted Single Frequency, Long Range M-sequences while underway at 4.5knots. At the station stops we transmitted Multi-Frequency Station Stop M-sequences. The station stop triplets are centered at roughly 1-1/2, 2-1/2, and 3-1/2CZs from the DVLA. Station stops within the triplets are separated by 5km.

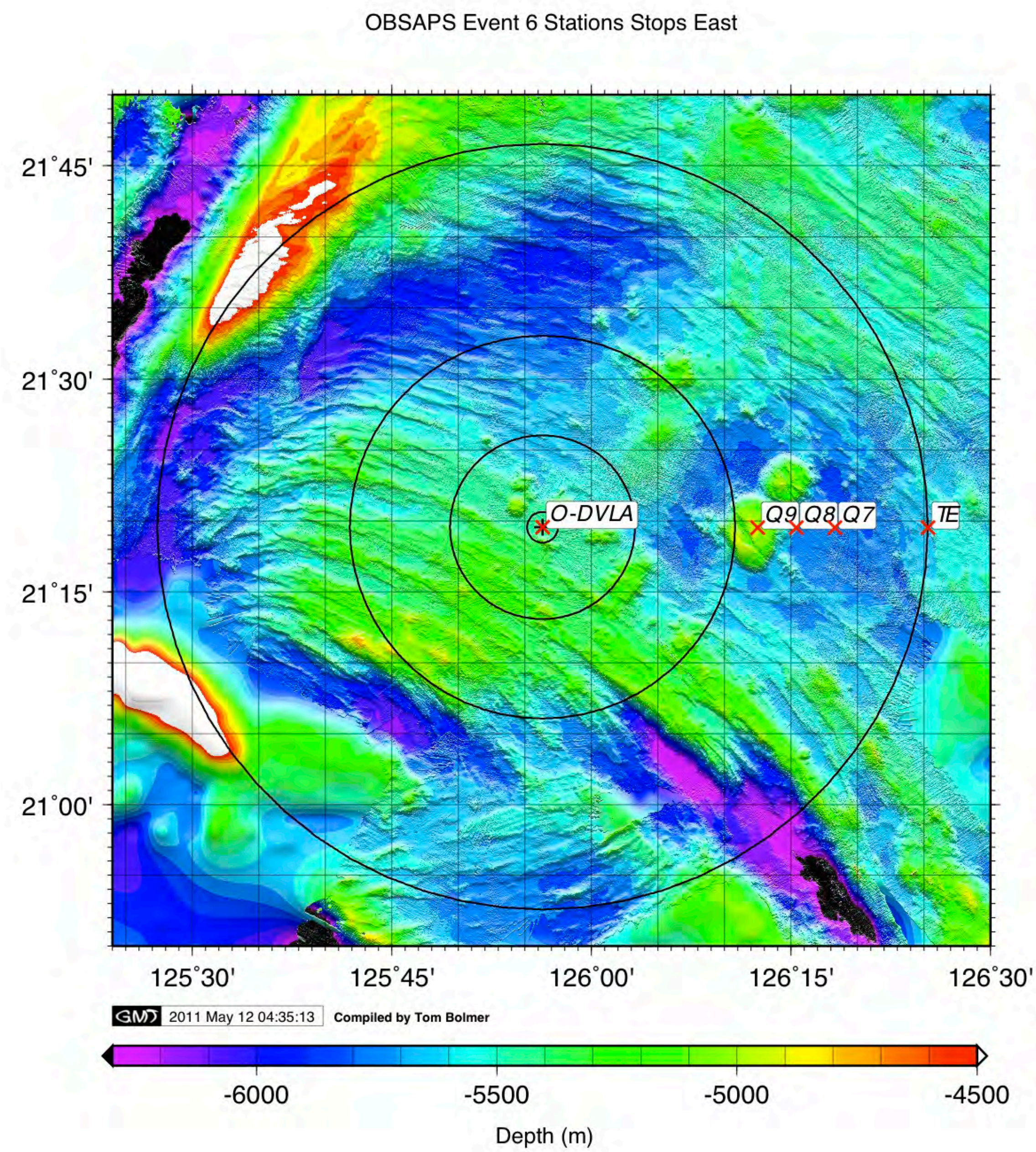


Figure 11f OBSAPS Event 6 Locations
Locations for Event #6, 1/2CZ station stops to the East (Q9, Q10, Q11 with Multi-Frequency Station Stop M-sequences), overlain on bathymetry. The fixed stations are separated by 5km at roughly 1/2 CZ from the DVLA.

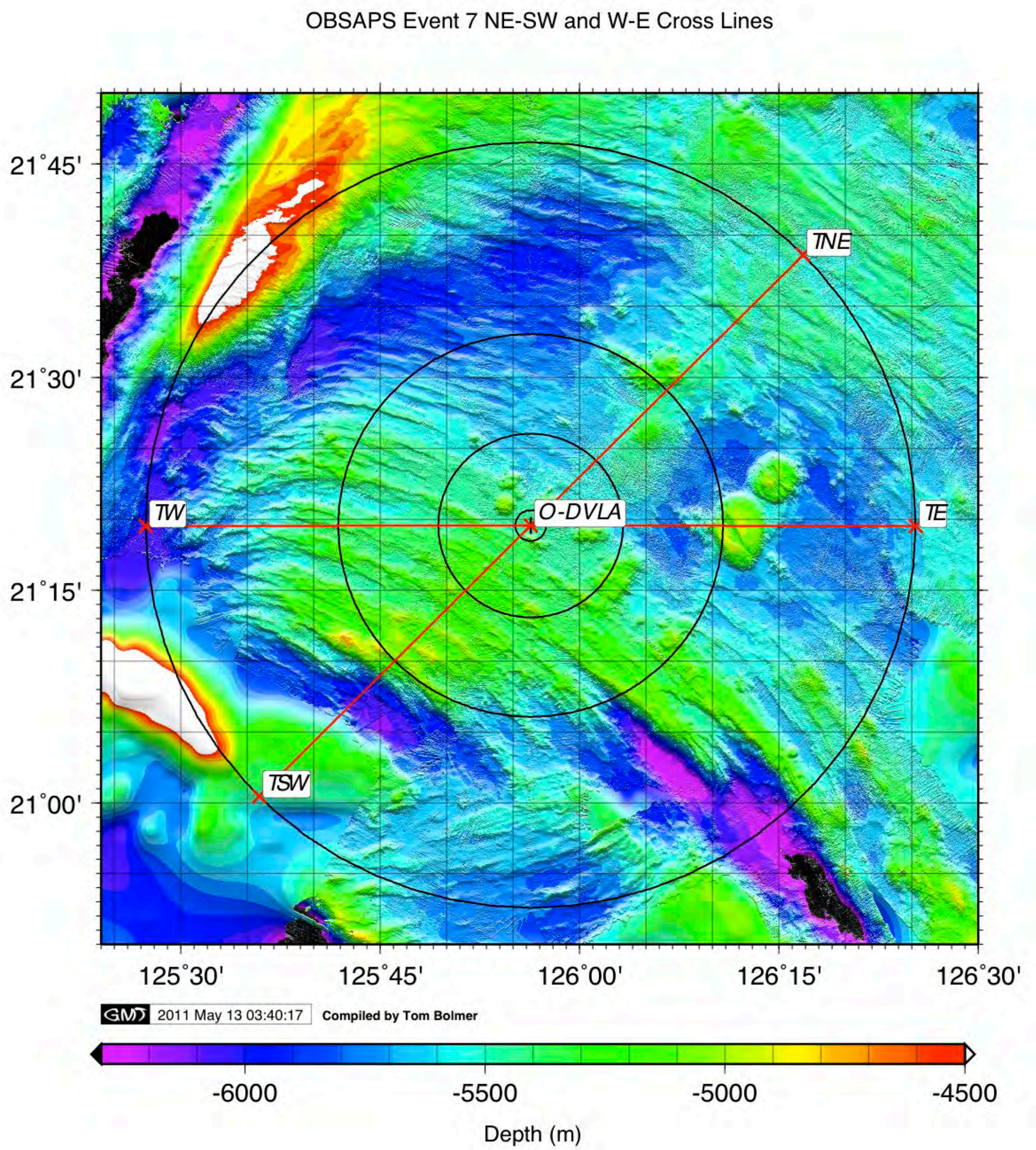


Figure 11g OBSAPS Event 7 Locations
Locations for Event #7, 50km Radials (at 2 knots using Short Range, Multi-Frequency M-sequences), East to West and Southwest to Northeast overlain on bathymetry.

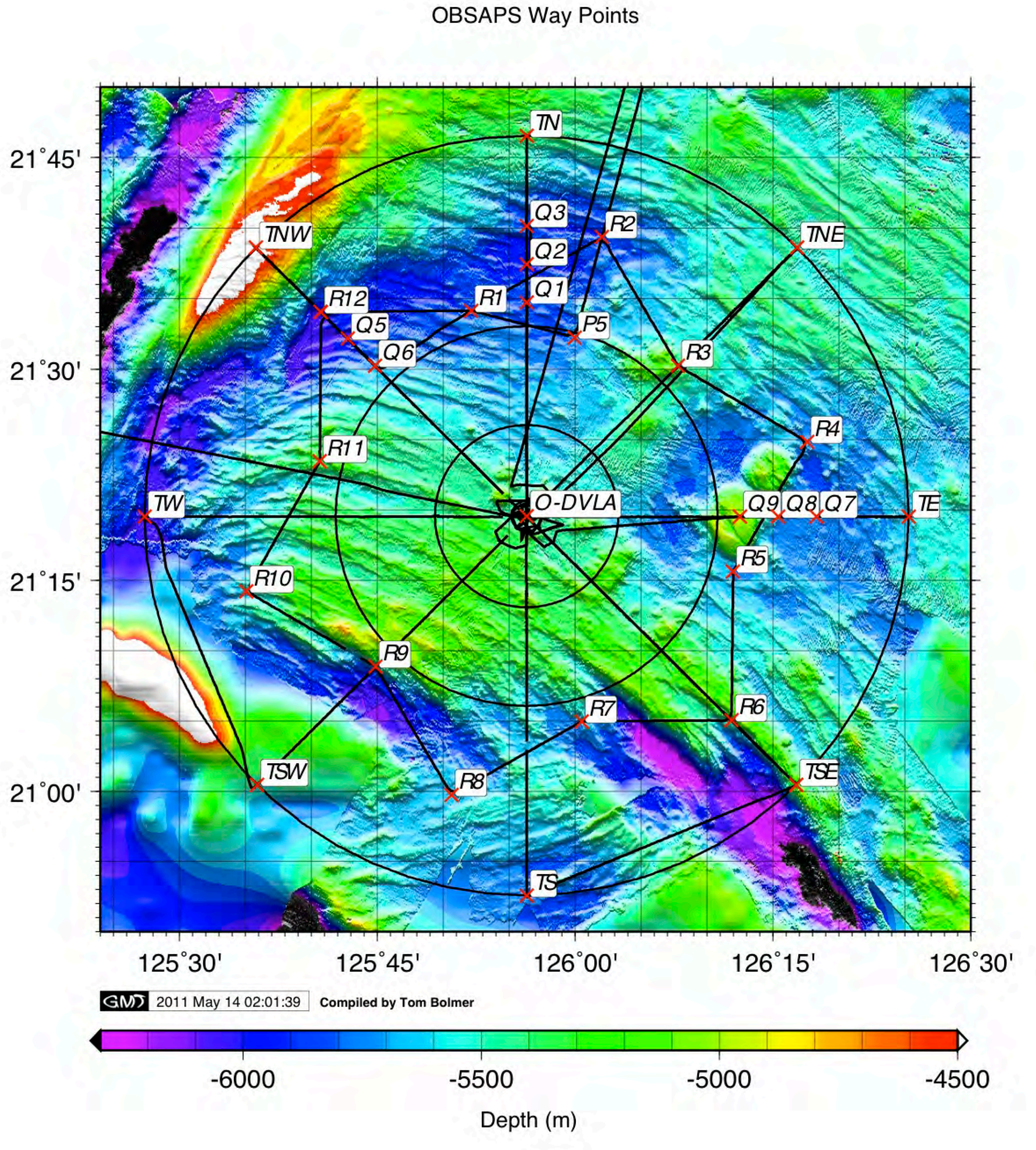


Figure 12 OBSAPS Cruise Tracks and Way-points
Summary of OBSAPS cruise tracks (black lines) and way-points (red x's). The black circles at 2, 12, 25 and 50km radius are not cruise tracks but are shown for scale. The long-line to the northeast (Figure 11e) is also not completely shown.

Table 1: Summary of OBSAPS Instruments and Data Sizes

Name	*Type*	*Number of Channels*	*Sample Rate (sps)*	*Number of Days*	*Sample Size (Bytes)*	*Data Size (Gigabytes)*
OBSs						
OBS-N	L-Cheapo OBS	4	1000	16	4	022
OBS-E	L-Cheapo OBS	4	1000	16	4	022
OBS-S	L-Cheapo OBS	4	1000	16	4	022
OBS-W	L-Cheapo OBS	4	1000	16	4	022
BBOBS-NW	Broadband OBS	4	200	16	4	4.5
BBOBS-SE	Broadband OBS	4	200	16	4	4.5
Total OBSs						**127.73**
Extra SIO Hydrophone Modules						
piggy back on OBS_N	SIO	1	1953.125	16	3	?
piggy back on OBS_E	SIO	1	1953.125	16	3	?
piggy back on OBS_W	SIO	1	1953.125	16	3	?
Total extra SIO hydrophone modules						**19.6**
DVLA	Hydrophone Array	15	1953.125	25	3	159
	Current Meter 10sec sample interval based on average of five one-second pings	1	1	33	4	000
Total DVLA						***253***

Name	*Type*	*Number of Channels*	*Sample Rate (sps)*	*Number of Days*	*Sample Size (Bytes)*	*Data Size (Gigabytes)*
J15-3 Source	Monitor Hydrophone	1	8000	14	4	036
	IRIG-B Time Signal	1	8000	14	4	036
	Sonobuoy	1	8000	14	4	036
	Power Amp Voltage	1	8000	14	4	036
	Power Amp Current	1	8000	14	4	036
	Druck depth sensor	1	8000	14	4	036
Total J15-3 Source						***218***
Total for Experiment						***343***

Table 2: Summary of OBSAPS Ancillary Data

Ancillary Data

Multibeam Bathymetry
3.5KHz Sub Bottom Profiler
Thermal-Salino Graph (TSG - surface temperature and salinity)
Ship ID (AIS)
XBT
XSV
CTD
Navigation
  Gyro
  GPS
Watch Logs
Meta data

Table 3: Revelle Schedule

Day	Date	JD	GMT	Local	Event
Monday	18-Apr-11	108	O-DVLA Started recording at 1607Z		Load ship
Tuesday	19-Apr-11	109		O-DVLA Started recording at 0007L	Sailing postponed due to engine trouble
Wednesday	20-Apr-11	110			
Thursday	21-Apr-11	111			
Friday	22-Apr-11	112			
Saturday	23-Apr-11	113			
Sunday	24-Apr-11	114			
Monday	25-Apr-11	115			
Tuesday	26-Apr-11	116			
Wednesday	27-Apr-11	117			
Thursday	28-Apr-11	118			
Friday	29-Apr-11	119	800Z	1600	Cast off from Kaohsiung at 1600L
Saturday	30-Apr-11	120			Begin transponder test at 0600L at an underway station stop but hydrowire fouled in fishing line. We did not deploy the J15. Underway to Site G by 0930L
Sunday	1-May-11	121			Start OBS deployments at 0400L and finish at 0830L. Started transmission program.
Monday	2-May-11	122			Transmission program
Tuesday	3-May-11	123			Transmission program. At 1515L had a "winch incident" with the J15-3 on deck.
Wednesday	4-May-11	124			Transmission program.
Thursday	5-May-11	125			Transmission Program
Friday	6-May-11	126			Transmission Program
Saturday	7-May-11	127			Transmission Program
Sunday	8-May-11	128			Transmission Program

Day	Date	JD	GMT	Local	Event
Monday	9-May-11	129			Transmission Program. Wait on weather 8hours.
Tuesday	10-May-11	130			Transmission program, stormy weather
Wednesday	11-May-11	131			Transmission Program
Thursday	12-May-11	132	O-DVLA stops recording at 1601Z		Transmission Program, Arrived at DVLA by 2400, 132JD1600
Friday	13-May-11	133		O-DVLA stops recording at 0001	Started OBS recoveries at DVLA at 0015 Friday, 132JD1615
Saturday	14-May-11	134			Finished recoveries: OBS: 1410L, 0610Z O-DVLA: 1500L-1810, 0700Z-1010Z Transponders: 1830L 1030Z
Sunday	15-May-11	135			Transit
Monday	16-May-11	136	0000Z		Arrive Kaohsiung at 0800L & Unload

Table 4: Time line for the Transmission Program

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
Start at DVLA					0.0	121JD0030				
Event #1: 1/2 CZ Station Stops to the North										
DVLA to Q1	28.0	15.1	12.0		1.3	121JD0130	1	1	0.0	1.0
CTD at Q1 (At same time as J15-3??)					6.0	At same time as J15-3.				
Deploy J15-3					0.5	121JD0200	0.5	1.5	0.0	1.5
Test Source					2.0	121JD0615	4.25	5.75	0.0	5.8

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
SS#1 - 1/2 CZ to the North					14.0	121JD2115	15	20.75	0.0	20.8
3 positions (Q1, Q2, and Q3 , 4 hours each,										
plus transit 15km, 5km separation)										
Q3 to TN	12.0	6.5	6.0		1.1	121JD2315	2	22.75	0.0	22.8
Event #2: 50km Radials, N-S and SE-NW						Change-out J15-3	4.5	27.25	1.0	3.3
Transmit from	100	54.0	2	0.3	27.0	123JD0515	25.5	52.75	2.0	4.8
TN to TS										
Recover J15-3					0.5	123JD0530, At 123JD0715 (1515L) had a "winch	0.25	53	2.0	5.0

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
						incident" with the J15-3 on deck.				
Transit from	38.3	20.7	12.0		1.7	123JD0830,	3	56	2.0	8.0
TS to TSE										
Deploy J15-3					0.5	123JD0845	0.25	56.25	2.0	8.3
Transmit from	100	54.0	2	0.3	27.0	124JD1245	28	84.25	3.0	12.3
TSE to TNW										
TNW to Q4	12.0	6.5	6.0		1.1	124JD1345	1	85.25	3.0	13.3
Event #3: 1/2 CZ Station Stops to the Northwest						Change-out J15-3	3.25	88.5	3.0	16.5

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
CTD					6.0	At same time as J15-3. Started down at 124JD1350 and back up at ????.				
SS#2 - 1/2 CZ to the Northwest					14.0	J15-3 (#14) down at 124JD1415Z but pulled it because of current overloads. Replacement J15-3 (#11) down by 124JD1700Z .				
3 positions (Q4, Q5, and Q6 , 4 hours each,						4hour program at Q4, and 2hour programs at each of Q5 and Q6. Finished by	11	99.5	4.0	3.5

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
						125JD0400				
plus transit 15km, 5km separation)										
Q6 to R1	14.5	7.8	5.0		1.6	At 125JD0400 started speed tests with 80 and 100m wire out en route to R1.	2	101.5	4.0	5.5
Event #4: Star of David										
12 lines from	236.0	127.4	4.5		28.3	Started Star at 125JD0600 and finished at 126JD0830	26.5	128	5.0	8.0

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
R1 thru R12										
and back to R1										
Transit from R1	28.0	15.1	8.0		1.9	Arrived at P5 126JD1000	1.5	129.5	5.0	9.5
to DVLA-G, changed to P5 for long-line										
Event#5 - 250km Long Lines										
Deploy J15-3					0.5	Not necessary, left J15-3 in the water.				
Transmit from P5 to Q10	65.8	35.5	4.5	0.7	7.9	Arrived Q10 126JD1800	8	137.5	5.0	17.5

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
SS#4 - 1-1/2CZ towards S8					9.0	Leaving Q12 at 127JD0300, 1100L	9	146.5	6.0	2.5
3 positions (Q10, Q11, Q12) + transit, 4hrs each										
(possibly different source depths)										
Transmit from Q12 to Q13	55.0	29.7	4.5	0.7	6.6	Arrive Q13 about 127JD0940, 1740L	6.7	153.2	6.0	9.2
SS#4 - 2-1/2CZ towards S8					9.0	Finish Q15 at 127JD1915, 0315L	9.5	162.7	6.0	18.7
3 positions (Q13, Q14, Q15) + transit, 4hrs each										
(possibly different source depths)										
Transmit fromQ15 to Q16	55.0	29.7	4.5	0.7	6.6	Arrive Q16, 128JD0225 1025L	7	169.7	7.0	1.7
SS#4 - 3-1/2CZ towards S8					9.0					

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
3 positions (Q16, Q17, Q18) + transit, 4hrs each						Finish Q18, 128JD1130 1930L	9	178.7	7.0	10.7
(possibly different source depths)										
Transmit from Q18 to P4	19.1	10.3	4.5	0.7	2.3	Finish long line, 2230L on Sunday night, 128JD1430	2.75	181.45	7.0	13.5
Recover J15-3					0.5		0.25	181.7	7.0	13.7
Transit from P4 to DVLA	250.0	135.0	11.0		12.3	Back at S5 FOR OBS SURVEY at 1100 Monday morning, 129JD0300	12.5	194.2	8.0	2.2
CTD					6.0	Bag this CTD				

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
Navigate OBSs					24.0	Finish OBS navigation at 1730L Monday evening, 129JD0930	6.5	200.7	8.0	8.7
Event #6: 1/2 CZ Station Stops to the East										
S8 to Q9	24.1	13.0	8.0		1.6	At Q9 1900L Monday, 129JD1100	1.5	202.2	8.0	10.2
CTD					6.0	Did CTD from 1918 to 2220L, 129JD1420	3.5	205.7	8.0	13.7
						Waited on weather (WOW) until Tuesday AM.	8	213.7	8.0	21.7

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
Deploy J15-3					0.5	0650L Tuesday, 129JD2250				
SS#3 - 1/2 CZ to the East					9.0					
3 positions (Q9, Q8, and Q7 , 2 hours each,										
5km separation)						Finish Q7 at 1650L, 130JD0850	10	223.7	9.0	7.7
Q7 to TE	12.0	6.5	2.5		2.6	At TE by 1840L Tuesday, 130JD1040	2	225.7	9.0	9.7
Event #7: 50km Radials, E-W and SW-NE										

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
Transmit from	100	54.0	2	0.3	27.0	Bad storm with winds sustained at 40 and gusts to 48kts for TE to DVLA, calm seas for DVLA to TW, arrived TW at 1830L Wednesday, 131JD1030	24	249.7	10.0	9.7
TE to TW										
Acquire 30minutes of Primary 4CW and other linearity tests - Recover J15-3					1.0	Left TW at 1920L, 131JD1120	1	250.7	10.0	10.7
Transit from	38.3	20.7	11.0		1.9	Arrive TSW at 2130, 131JD1330	2	252.7	10.0	12.7

Event	Distance (km)	Distance (nmi)	Speed (kts)	5min Shot Sep (km)	Planned Duration (hrs)	Actual time	Actual Duration (hrs)	Cumulative Hours	Cumul. Days	Hours
TW to TSW										
Deploy J15-3					0.5	Leave TSW at Wednesday 2150,131JD 1350	0.3	253	10.0	13.0
Transmit from	100	54.0	2.5	0.3	21.6	Adjust speed to available time.				
TSW to TNE, go to DAC gain of 2.5?						Arrive TNE at Thursday, 1830, 132JD1030	21	274	11.0	10.0
Station tests and recover J15-3					0.5	Finish by 2000, 132JD1200	1.5	275.5	11.0	11.5
TNE to DVLA	50.0	27.0	8.0		3.4	Arrived at DVLA by 2400, 132JD1600	4	279.5	11.0	15.5

Table 5: Coordinates of way-points and instrument locations

Sites	*Latitude*			*Longitude*			*Latitude*	*Longitude*
	Deg.	Decimal Minute		Deg.	Decimal Minute		Decimal Degree	Decimal Degree
Way-points out:								
Ships WP6:	21	15.6	N	121	21.	E	21.26N	121.36E
New Ships WP6a:	21	36	N	122	0	E	21.6N	122E
New Ships WP6b:	21	30	N	125	0	E	21.5N	125E
Underway Station Stop:	21	35.61	N	122	16.012	E	21.5935N	122.267E
Way-points home:								
New Ships WP6c:	21	13	N	125	30	E	21.2167N	125.5E
New Ships WP6d:	21	16	N	123	0	E	21.2667N	123E
New Ships WP6e:	21	19	N	122	0	E	21.3167N	122E
New Ships WP6f:	21	22	N	121	30	E	21.3667N	121.5E
Ocean Bottom Seismometers - nominal drop positions:								
OBS1 - OBSN	21	20.6382	N	125	56.325	E	21.34397	125.9387
OBS2 - OBSE	21	19.5589	N	125	57.4835	E	21.32598	125.9581
OBS3 - OBSS	21	18.35	N	125	56.6458	E	1.30583	125.9441
OBS4 - OBSW	21	19.5589	N	125	55.1665	E	21.32598	125.9194
OBS5 - BBOBSSE	21	18.7958	N	125	57.1441	E	21.31326	125.9524
OBS6 - BBOBSSW	21	18.7958	N	125	55.5059	E	21.31326	125.9251
OBS Final Seafloor Navigated Locations								
OBS1 – OBSN	21	20.8316	N	125	56.1601	E	21.34719	125.936
OBS2 – OBSE	21	19.537	N	125	57.51	E	21.32562	125.9585
OBS3 – OBSS	21	18.2867	N	125	56.4779	E	21.30478	125.9413
OBS4 – OBSW	21	19.5387	N	125	55.1455	E	21.32565	125.9191

Sites	***Latitude***			***Longitude***			***Latitude***	***Longitude***
	Deg.	Decimal Minute		Deg.	Decimal Minute		Decimal Degree	Decimal Degree
OBS5 – BBOBSSE	21	18.5955	N	125	57.4424	E	21.30992	125.9574
OBS6 – BBOBSSW	21	18.7481	N	125	55.4552	E	21.31247	125.9243
Mooring O-DVLA (OBSAPS Distributed Vertical Line Array, actual navigated position)								
O_DVLA	21	19.5594	N	125	56.3247	E		
Source Transmission Program								
TN	21	46.5391	N	125	56.3247	E	21.77565	125.9387
TS	20	52.5798	N	125	56.3247	E	20.87633	125.9387
TSE	21	00.4614 1	N	126	16.7604	E	21.00769	126.2793
TNW	21	38.6161	N	125	35.8002	E	21.6436	125.5967
TE	21	19.5181	N	126	25.2874	E	21.3253	126.4215
TW	21	19.5181	N	125	27.3619	E	21.3253	125.456
TSW	21	00.4614 1	N	125	35.889	E	21.00769	125.5981
TNE	21	38.6161	N	126	16.8491	E	21.6436	126.2808
Q1	21	34.7324	N	125	56.3247	E	21.57887	125.9387
Q2	21	37.4418	N	125	56.3247	E	21.62403	125.9387
Q3	21	40.1512	N	125	56.3247	E	21.66919	125.9387
Q4	21	34.0656	N	125	40.7135	E	21.56776	125.6786
Q5	21	32.1583	N	125	42.7706	E	21.53597	125.7128
Q6	21	30.2506	N	125	44.8267	E	21.50418	125.7471
Q7	21	19.5357	N	126	18.302	E	21.32559	126.305
Q8	21	19.5415	N	126	15.4103	E	21.32569	126.2568
Q9	21	19.5466	N	126	12.5185	E	21.32578	126.2086
P5	21	32.2463	N	125	59.9793	E	21.53744	125.9997
Q10	22	06.6389	N	126	09.9428	E	22.11065	126.1657
Q11	22	09.2537	N	126	10.7037	E	22.15423	126.1784
Q12	22	11.8685	N	126	11.4651	E	22.19781	126.1911
Q13	22	40.6261	N	126	19.8718	E	22.6771	126.3312

Sites	***Latitude***			***Longitude***			***Latitude***	***Longitude***
	Deg.	Decimal Minute		Deg.	Decimal Minute		Decimal Degree	Decimal Degree
Q14	22	43.24	N	126	20.6389	E	22.72067	126.344
Q15	22	45.8538	N	126	21.4065	E	22.76423	126.3568
Q16	23	14.6005	N	126	29.8827	E	23.24334	126.498
Q17	23	17.2134	N	126	30.6563	E	23.28689	126.5109
Q18	23	19.8262	N	126	31.4303	E	23.33044	126.5238
P4	23	29.7886	N	126	34.3866	E	23.49648	126.5731
R1	21	34.1523	N	125	52.1199	E	21.56921	125.8687
R2	21	39.3637	N	126	02.0346	E	21.65606	126.0339
R3	21	30.2363	N	126	07.8073	E	21.50394	126.1301
R4	21	24.8441	N	126	17.5992	E	21.41407	126.2933
R5	21	15.637	N	126	11.9843	E	21.26062	126.1997
R6	21	05.0487	N	126	11.8638	E	21.08414	126.1977
R7	21	04.9648	N	126	00.5156	E	21.08275	126.0086
R8	20	59.752	N	125	50.6403	E	20.99587	125.844
R9	21	08.8696	N	125	44.8698	E	21.14783	125.7478
R10	21	14.2302	N	125	35.0758	E	21.23717	125.5846
R11	21	23.4577	N	125	40.6512	E	21.39096	125.6775
R12	21	34.0463	N	125	40.7343	E	21.56744	125.6789

Table 6: OBSAPS OBS locations

Tom Bolmer May 15,2011

OBS	*Latitude*			*Longitude*			*Depth*
	deg	*min*	*decimal*	*deg*	*min*	*decimal*	*meters**
Matlab Calculated OBS Sites							
OBS-1	21	20.6382	21.3440	125	56.3250	125.9387	5436.87
OBS-2	21	19.5589	21.3260	125	57.4835	125.9581	5416.77
OBS-3	21	18.3500	21.3058	125	56.6458	125.9441	5068.24
OBS-4	21	19.5589	21.3260	125	55.1665	125.9194	5433.19
OBS-5	21	18.7959	21.3133	125	57.1441	125.9524	5405.41
OBS-6	21	18.7959	21.3133	125	55.5059	125.9251	5397.82
OBS Release Sites							
OBS-1	21	20.6370	21.3439	125	56.3250	125.9387	5437.19
OBS-2	21	19.5580	21.3260	125	57.4830	125.9581	5416.77
OBS-3	21	18.3510	21.3058	125	56.6460	125.9441	5068.24
OBS-4	21	19.5580	21.3260	125	55.1630	125.9194	5433.19
OBS-5	21	18.7960	21.3133	125	57.1440	125.9524	5405.41
OBS-6	21	18.7950	21.3133	125	55.5050	125.9251	5397.82
OBS Surveyed Sites							
OBS-1	21	20.8316	21.3472	125	56.1601	125.9360	5447.07 **
OBS-2	21	19.5370	21.3256	125	57.5100	125.9585	5411.07
OBS-3	21	18.2867	21.3048	125	56.4779	125.9413	5214.27
OBS-4	21	19.5387	21.3256	125	55.1455	125.9191	5431.96
OBS-5	21	18.5955	21.3099	125	57.4424	125.9574	5447.11
OBS-6	21	18.7481	21.3125	125	55.4552	125.9243	5395.47

* All of these depths are estimated by Tom Bolmer from his multi-beam data set (125m grid size) and the given OBS locations.

** - Depths in OBSIP files are 5440, 5423, 5077, 5431, 5405 and 5398 respectively.
These depths are not computed from the acoustic survey. They are from the ship's multi-beam at the drop location (OBS release sites)

Table 7: OBSAPS DVLA (Anchor) and Transponder Locations

OBSAPS 13 April 2011

site	rfrq	n	N	dop	dr	toff	dt	lat	lon	dep	mb	dz
anchor	11.0	39	30	1.46	1.90	-0.15	1.24	21.3259904	125.9387447	5438.1	5446	-7.9
xpndr	11.0	196	95	0.57	1.86	-0.03	1.27	21.3345783	125.9461665	5415.8	5427	-11.2
xpndr	11.5	258	95	0.75	1.34	-0.32	0.90	21.3193960	125.9465069	5445.3	5462	-16.7
xpndr	12.0	109	95	0.82	0.66	-0.08	0.90	21.3194639	125.9299289	5426.7	5421	5.7
xpndr	12.5	114	95	0.65	0.87	0.02	1.56	21.3349753	125.9297470	5427.0	5445	-18.0

site	rfrq	lat	lon	dep	lat	lon
anchor	11.0	21.3259904	125.9387447	5438.1	21 19.559N	125 56.325E
xpndr	11.0	21.3345783	125.9461665	5415.8	21 20.075N	125 56.770E
xpndr	11.5	21.3193960	125.9465069	5445.3	21 19.164N	125 56.790E
xpndr	12.0	21.3194639	125.9299289	5426.7	21 19.168N	125 55.796E
xpndr	12.5	21.3349753	125.9297470	5427.0	21 20.099N	125 55.785E

6. OBSAPS Signal Menu – April – May 2011

This is a summary of the signals that we transmitted on the OBSAPS cruise from R/V Revelle, 18 April to 17 May, 2011. We had an 11.6-day transmission program summarized in Table 3 and detailed in Appendix 1. Except for a few engineering tests, all of the transmissions on OBSAPS were M-sequences (phase-coded linear maximal shift register sequences). There were three primary formats:

Multi-Frequency M-sequence, Short-Range Tows (see Note e)

center frequencies of 77.5Hz, 155Hz and 310Hz
2, 4, and 4 cycles/digit respectively
11bit law
4 sample/cycle
4 periods
duration at 77.5Hz, 2 cycles/digit, is 105.6sec plus 14.4sec gap = 120sec
duration at 155Hz, 4 cycles/digit, is 105.6sec plus 14.4sec gap = 120sec
duration at 310Hz, 4 cycles/digit, is 52.8sec plus 7.2sec gap = 60sec
Total duration 300sec (5min) repeated continuously, at 2knots gives 0.3km spacing.
filename: OBSAPS_Primary_Sea_04_3_4K.sio
created in: OBSAPS_Primary_4_Sea_3.m

Single Frequency M-sequence, Long-Range Tows (see Note f)

center frequency of 77.5Hz
2 cycles/digit
11bit law
4 sample/cycle
25 periods
duration is 660sec (11min), no gap, repeated continuously, at 4.5knots gives 0.675km spacing.
filename: OBSAPS_Primary_Sea_05_3_4K.sio
created in: OBSAPS_Primary_5_Sea_3.m

M-sequences, Multi-Frequency Station Stops (see Note g)
(This format was too large to fit in the available memory of the acquisition system, so it was broken into three pieces. They were repeated hourly at 15min, 35min, and 53min past the hour respectively for a, b and c.)

center frequency of 77.5Hz
2 cycles/digit
11bit law
4 sample/cycle
37 periods (26.4sec each)
duration is 976.8sec, plus 43.2sec gap = 1020sec (17min)
filename: OBSAPS_Primary_Sea_06a_3_4K.sio

created in: OBSAPS_Primary_6a_Sea_3.m

center frequencies of 155Hz and 310Hz
2 cycles/digit
11bit law
4 sample/cycle
37 periods
duration at 155Hz is 488.4sec plus 21.6sec gap = 510sec (8.5min)
duration at 310Hz is 244.2sec plus 25.8sec gap = 270sec (4.5min)
Total duration is 13min.
filename: OBSAPS_Primary_Sea_06b_3_4K.sio
created in: OBSAPS_Primary_6b_Sea_3.m

center frequencies of 102.3Hz and 204.6Hz
2 cycles/digit
11bit law
4 sample/cycle
37 periods
duration at 102.3Hz, 2 cycles/digit, is 740sec plus 10sec gap = 750sec (12.5min)
duration at 204.6Hz, 2 cycles/digit, is 370sec plus 20sec gap = 390sec (6.5min)
Total duration 19min.
filename: OBSAPS_Primary_Sea_06c_3_4K.sio
created in: OBSAPS_Primary_6c_Sea_3.m

Some notes:

a) We transmitted on only one J15-3 at a time, although we brought along two units to have a spare. We needed both of them.

b) All transmissions were at less than 100m water depth, with the primary depth around 60m. Depth is variable because it depends on ship's speed through the water, which is variable. We tried to keep a fixed speed over the ground, but currents can be large (> 1 knot) and unpredictable. The maximum cable length placed the J15-3 at 100m when stationary relative to the current.

c) The nominal source strength is 180dB re microPascal @ 1m in the band from 50 to 400Hz, but on previous cruises most of our transmissions were about 10dB less than this.

d) We transmitted primarily M-sequences that can be compressed to pulses for identifying multi-paths and Deep Seafloor Arrivals (DSFAs). We had no prior experience observing DSFAs at short ranges and in the Philippine Sea environment. The only previous observation of DSFAs was on NPAL04 in the North Pacific at ranges greater than 500km. This was "guided wave propagation" as opposed to "convergence zone propagation" that we will be observed on OBSAPS. We had little knowledge of the SNRs necessary to observe DSFAs. Our experience on NPAL04 suggested that the DSFAs on OBSs on the seafloor would have SNRs 10dB lower

than those on hydrophones at the conjugate depth. Planning was based on at least 20dB, and ideally 40dB, of estimated SNR at the conjugate depth at the half-convergent zone ranges. Since DSFAs may readily be observed in the shadow zones between convergent zones, we transmitted continuously along radial lines out to 250km.

e) Multi frequency, short range tows:

The plan was to transmit 77.5Hz, 155Hz, and 310Hz transmissions continuously along the eight radial lines and "star of David" inside 1/2CZ (35km). The goals were:
i) check for evidence of DSFAs.
ii) check the frequency dependence of bottom interaction at "lift-off" near 1/2CZ ranges.
iii) check the frequency dependence of bottom bounce paths which are most significant at these short ranges.
The direct path provides efficient propagation out to 1/2CZ ranges so we will have good SNRs using a shorter M-sequence repetition rate (only four replications of each frequency). We trade this off against higher frequencies and shot separation. By keeping the transmission sequence around 5 minutes and steaming at 2knots we get about 0.3km shot spacing. Previous experiments have shown significant amplitude changes in bottom arrivals over 0.5km or so.

f) Single frequency, long range tows:

We transmitted only 77.5Hz M-sequences (25 periods in eleven minutes) for ranges from 1/2CZ to 250km (about 4CZs). The long line at N15degE had essentially complete bottom excess everywhere (as on NPAL04). This line will be the closest we will come to replicating the NPAL04 conditions. We originally planned to steam this line at 6.0knots but because of operational concerns with the towing configuration we slowed to 4.5knots.

g) Multi-frequency, station stops.

At the station stops we transmitted M-sequences at 77.5Hz, 102.3Hz, 155Hz, 204.6Hz and 310Hz with 37periods each. By stacking individual pulses we could further increase the SNR by at least 10dB. The transmission program was arranged to have a gap around the time, at 50minutes past the hour, when the hydrophone modules were not acquiring acoustic data. At each stop we acquired between two and four samples (between 2 and 4 hours) of this format. Three station stops, 5km apart, are planned at 1/2CZ, 1-1/2CZ, 2-1/2CZ and 3-1/2CZ (about 30km, 90km, 150km and 210km). These stations will give us the best SNR at ranges with the strongest insonification of the bottom sensors assuming no bathymetric blockage.

7. Auxilliary Data

7a. CTD

Cast #	*Day of Year*	*Date*	*Start Time (UTC)*	*Latitude*			*Longitude*			*Max Depth (meters)*
01_Q1	121	05/01/11	01:57	21	34.76	N	125	56.29	E	5979
01_Q4	124	05/04/11	13:50	21	34.065	N	125	40.71	E	6124
03_Q9	129	05/09/11	11:05	21	34.065	N	125	12.334	E	5070
04_DVLA	134	05/14/11	06:59	21	19.558	N	125	56.321	E	5551

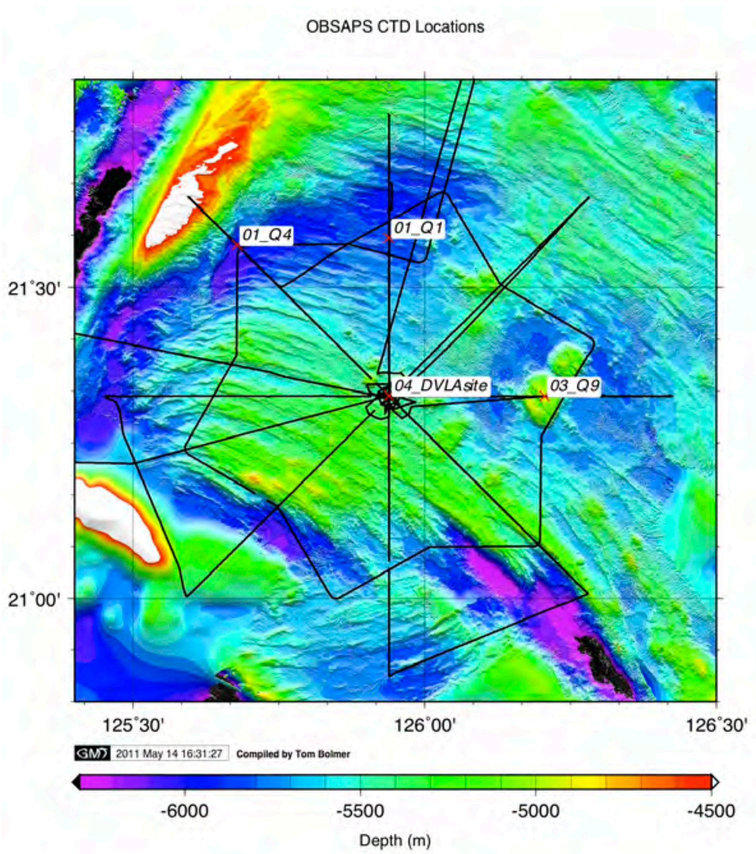


Figure 13 CTD Locations

7b. XBT and XSV

XBT #	*Date*	*Time (UTC)*	*Latitude*	*Longitude*	*Probe Type*	*Rated Max Depth (meters)*	*File name*
04	04/29/11	17:57	21.46629	121.445003	Fast deep	1000	TF_00004.EDF
05	04/30/11	05:18	21.56562	123.094922	T-5	1830	T5_00005.EDF
06	04/30/11	05:38	21.56328	123.161035	Fast Deep	1000	TF_00006.EDF
07	05/01/11	10:40	21.60226	125.938703	T-5	1830	T5_00007.EDF
08	05/01/11	10:45	21.61126	125.938638	T-5	1830	T5_00008.EDF
09	05/01/11	21:24	21.7016	125.938867	T-5	1830	T5_00009.EDF
10	05/02/11	07:54	21.58785	125.93872	T-5	1830	T5_00010.EDF
11	05/02/11	11:57	21.45266	125.938672	T-5	1830	T5_00011.EDF
12	05/02/11	16:13	21.30998	125.938655	T-5	1830	T5_00012.EDF
13	05/02/11	20:15	21.17518	125.93872	T-5	1830	T5_00013.EDF
15	05/03/11	00:31	21.0324	125.938785	T-5	1830	T5_00015.EDF
16	05/03/11	04:21	20.90408	125.938833	T-5	1830	T5_00016.EDF
18	05/03/11	09:40	21.01441	126.272152	T-5	1830	T5_00018.EDF
19	05/03/11	13:19	21.1008	126.179605	T-5	1830	T5_00019.EDF
20	05/03/11	18:25	21.22099	126.050749	T-5	1830	T5_00020.EDF
21	05/03/11	22:00	21.30569	125.9604	T-5	1830	T5_00021.EDF
22	05/04/11	02:21	21.40754	125.85026	T-5	1830	T5_00022.EDF
24	05/04/11	07:11	21.52165	125.727702	T-5	1830	T5_00024.EDF
25	05/04/11	11:36	21.62581	125.615722	T-5	1830	T5_00025.EDF
26	05/05/11	16:10	21.15378	126.19847	T-5	1830	T5_00026.EDF
27	05/06/11	00:17	21.17961	125.690087	T-5	1830	T5_00027.EDF
29	05/06/11	04:51	21.46224	125.678157	Fast Deep	1000	TF_00029.EDF
30	05/06/11	09:54	21.5424	125.9979	XSV-02	2000	S2_00030.EDF
31	05/06/11	16:30	22.02124	126.139827	T-5	1830	T5_00031.EDF
32	05/06/11	16:36	22.02911	126.142009	T-5	1830	T5_00032.EDF
34	05/07/11	00:11	22.17832	126.185417	T-5	1830	T5_00034.EDF
35	05/07/11	08:27	22.60015	126.308788	XSV-02	2000	S2_00035.EDF
36	05/08/11	00:09	23.08813	126.452228	T-5	1830	T5_00036.EDF
38	05/08/11	08:35	23.29736	126.514273	T-5	1830	T5_00038.EDF
40	05/09/11	04:59	21.32948	125.948485	T-5	1830	T5_00040.EDF
42	05/10/11	01:39	21.32619	126.223925	T-5	1830	T5_00042.EDF
43	05/11/11	07:26	21.32533	125.625292	XSV-02	2000	S2_00043.EDF
44	05/11/11	18:10	21.13621	125.73592	T-5	1830	T5_00044.EDF
45	05/11/11	22:38	21.2684	125.877652	T-5	1830	T5_00045.EDF

XBT #	*Date*	*Time (UTC)*	*Latitude*	*Longitude*	*Probe Type*	*Rated Max Depth (meters)*	*File name*
47	05/12/11	02:11	21.38061	125.99816	T-5	1830	T5_00047.EDF
48	05/12/11	10:24	21.63803	126.274868	T-5	1830	T5_00048.EDF

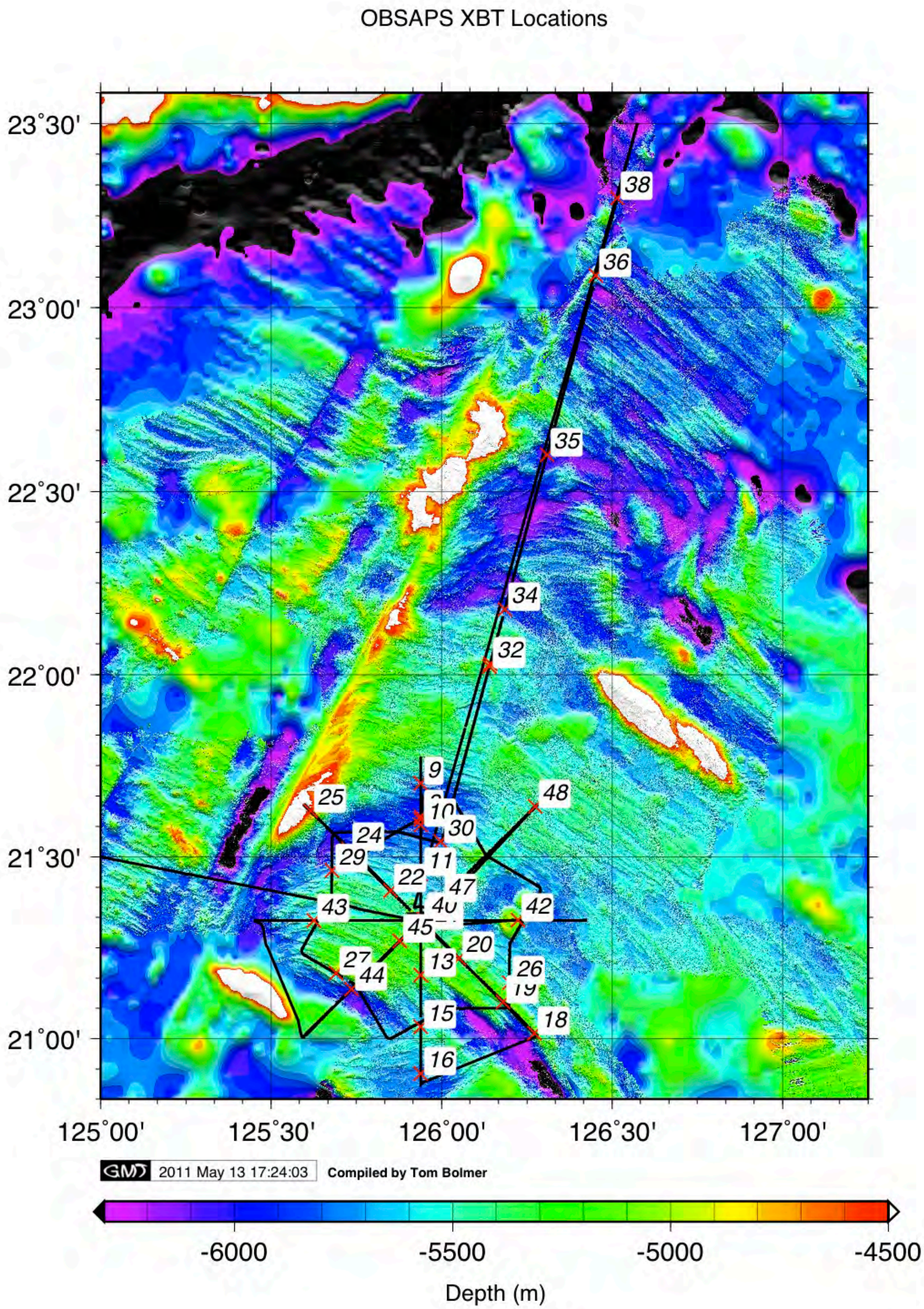


Figure 14a XBT and XSV Locations

7c: Sonobouys

Table 8: Sonobouys

Serial Number	Date/Time Deployed (GMT)	Longitude	Latitude	Configuration	Notes:
T010643	121 0320	125 56.302E	21 34.755N	CH16, 4hr, 400ft, CS, AGC off	
T010948	121 1155	125 56.316E	21 37.420N	CH16, 4hr, D3 (400ft), dF, AGC off	
T010417	122 0527	125 56.330E	21 40.148N	CH16, 4hr, D1(90ft), dF, AGC off	
T010414	122 1435	125 56.326E	21 22.065N	CH16, 4hr, D1, CS, AGC off	
???????	123 0950	126 16.329E	21 00.865N	CH16, 4hr, D1, CS, AGC off	This Sonobouy was deployed without recording the SN.
T010632	122 1422	126 09.315E	21 07.415N	CH16, 4hr, D1, CS, AGC off	
T010400	124 1442	125 40.712E	21 34.063N	CH16, 4hr, D1, CS, AGC off	
T010398	125 0813	126 02.2E	21 39.0N	CH16, 4hr, D1, CS, AGC off	
T010629	125 1450	126 11.986E	21 15.474N	CH16, 8hr, D1, CS, AGC off	
T010610	126 1010	125 59.98E	21 32.246N	CH16, 4hr, D1, CS, AGC off	
T010732	128 0530	126 30.53E	23 16.67N	CH16, 4hr, D1, CS, AGC off	This sonobouy did not deploy its float, back up sonobouy was deployed to replace it.
T010960	128 0530	126 30.53E	23 16.67N	CH16, 4hr, D1, CS, AGC off	

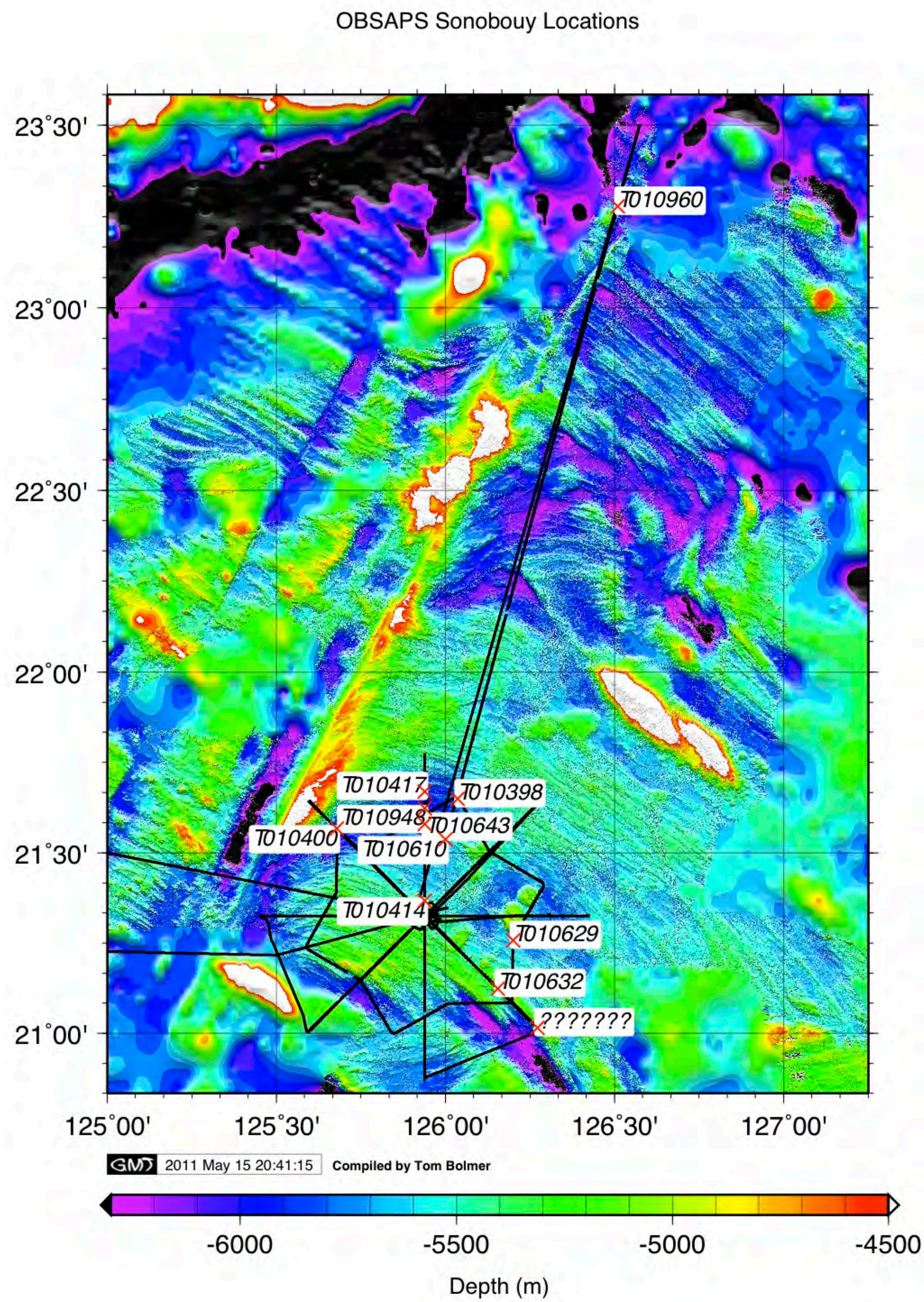


Figure 14b Sonobuoy Locations

7d. Current Meter

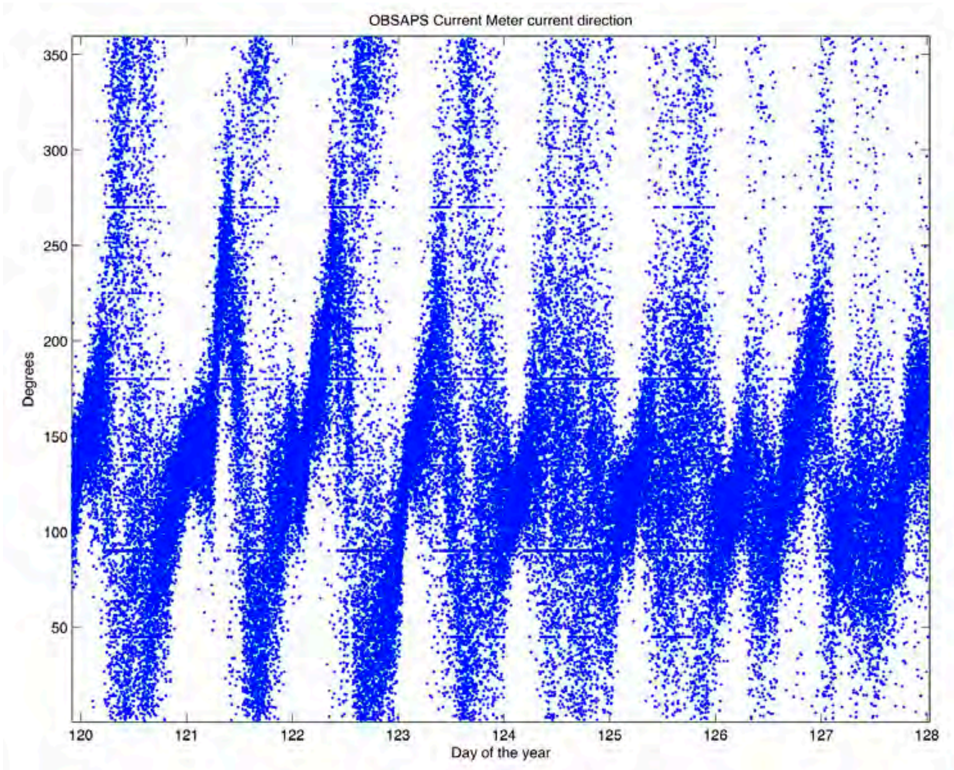


Figure 15 Sample of Seafloor Current Meter Data

7e. Seabird Depth and Temperature

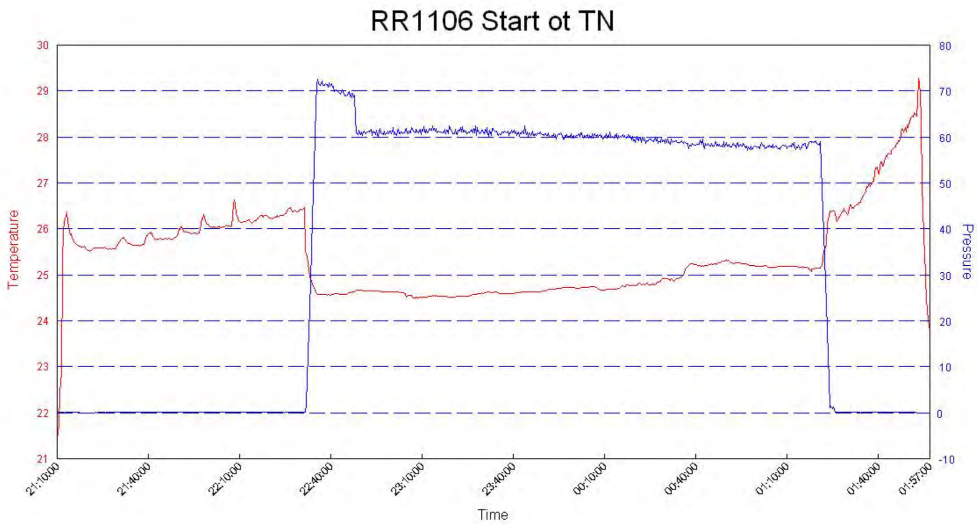


Figure 16 Example of Seabird Depth and Temperature Data
Example of Seabird temperature (degrees C) and pressure (decibars or depth in meters) data for the source tow starting at TN (121_0291). Seabird modules were strapped to the J15-3 source for most deployments.

7f. Automatic Identification System (AIS) Data

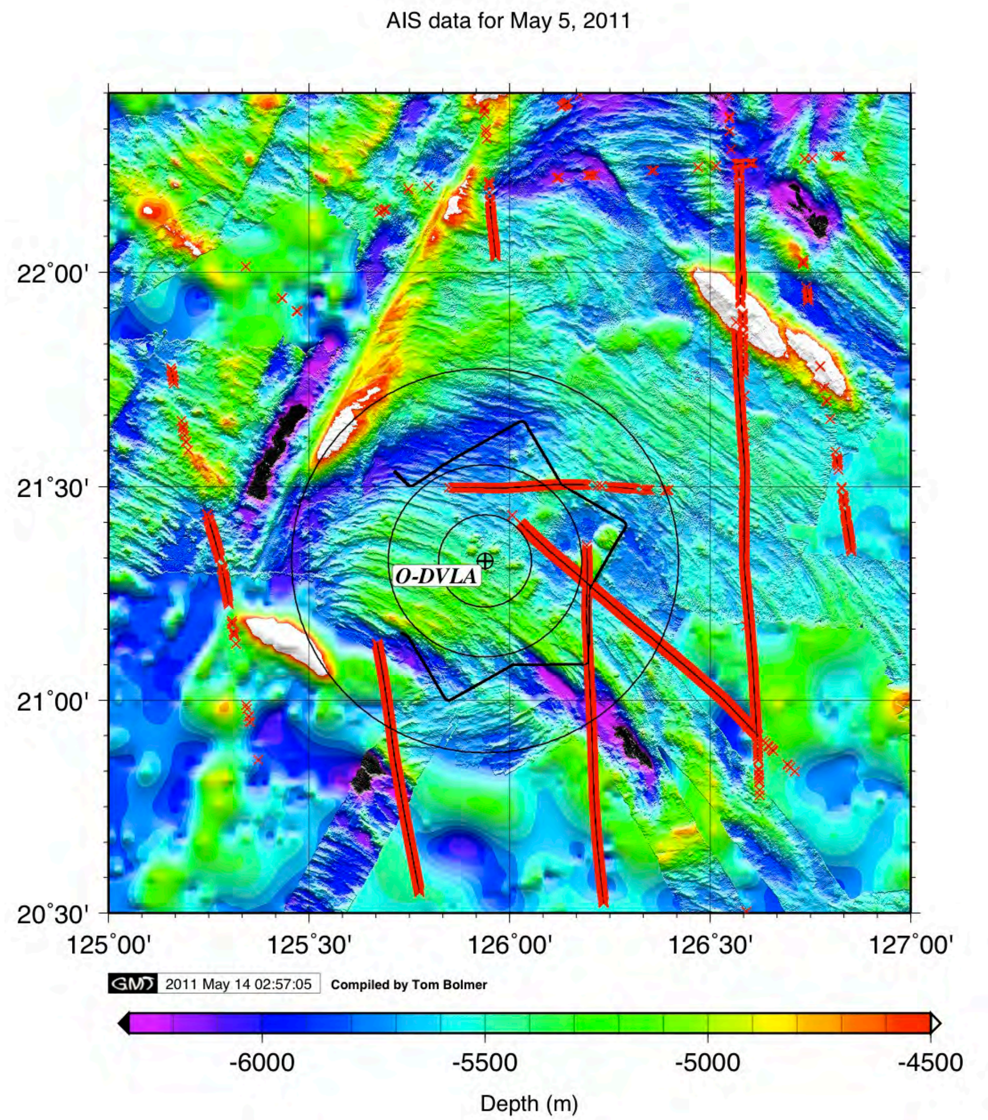


Figure 17 Example of AIS Data
Example of AIS Data. Red lines mark the tracks of ships that transited the OBSAPS area on May 5, 2011.

7g. Extended Multi-beam Coverage

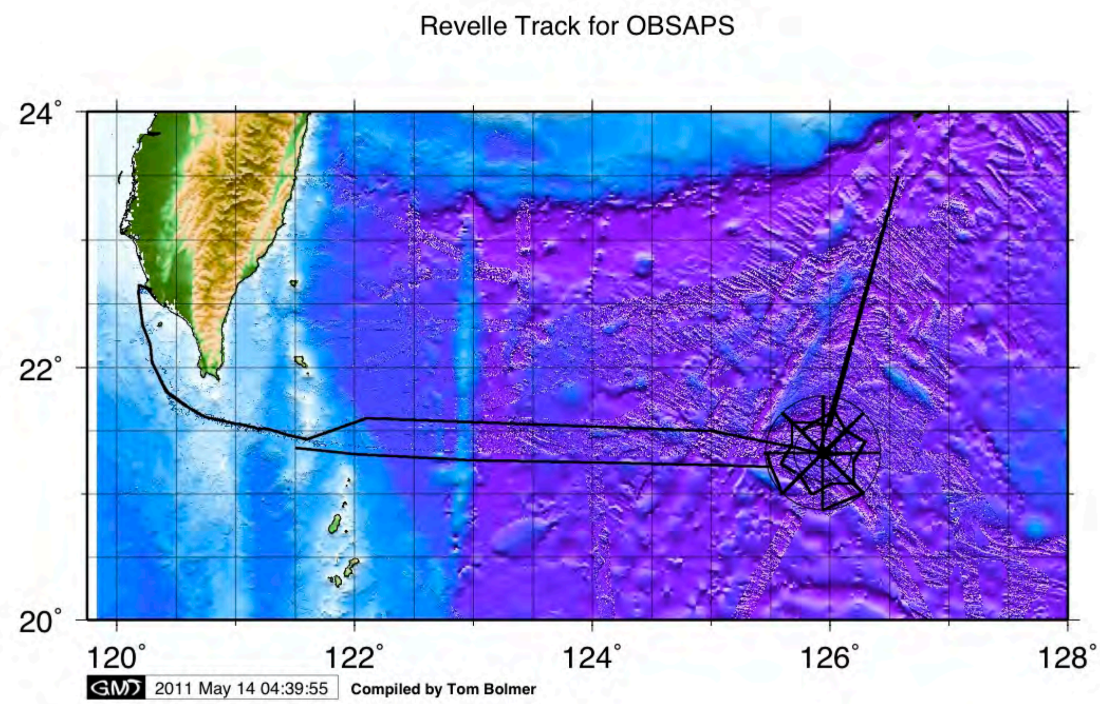


Figure 18 Ship Track Summary for the Whole Cruise with Expanded Multi-beam Coverage

Ship track summary for the whole cruise. Tracks to and from the OBSAPS site were offset to fill-in gaps in the available multi-beam data.

7h. Weather

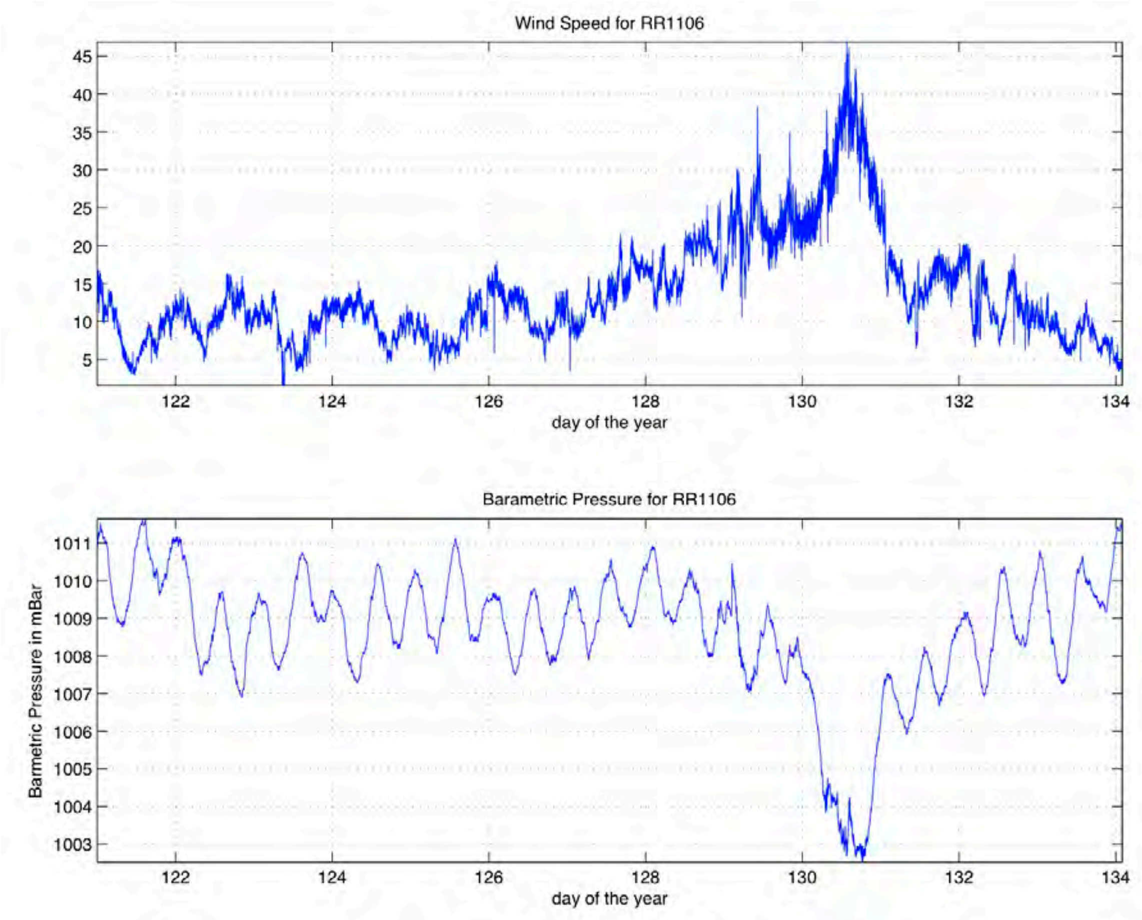


Figure 19 Wind Speed and Barometric Pressure Summary

7i. PE- CRAM models

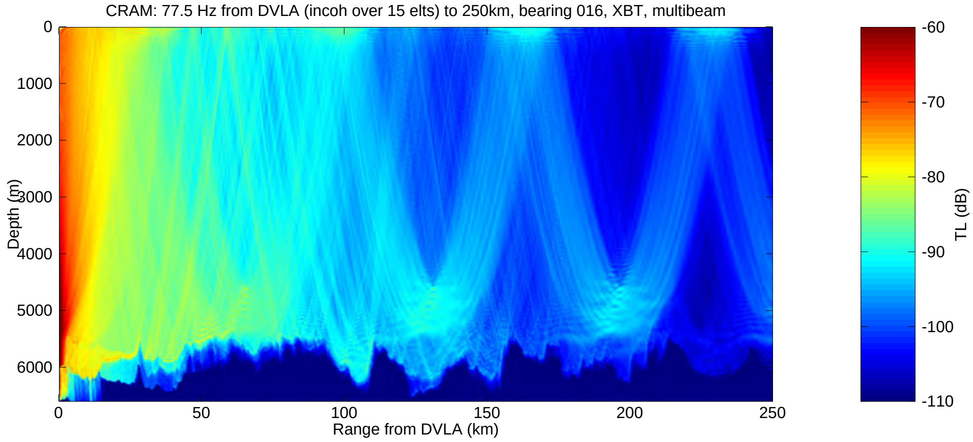


Figure 20 Transmission Loss Versus Range and Depth for the 250km Long Line
Transmission loss versus range and depth for the 250-km line at 77.5Hz with range-dependent bathymetry using PE-CRAM.

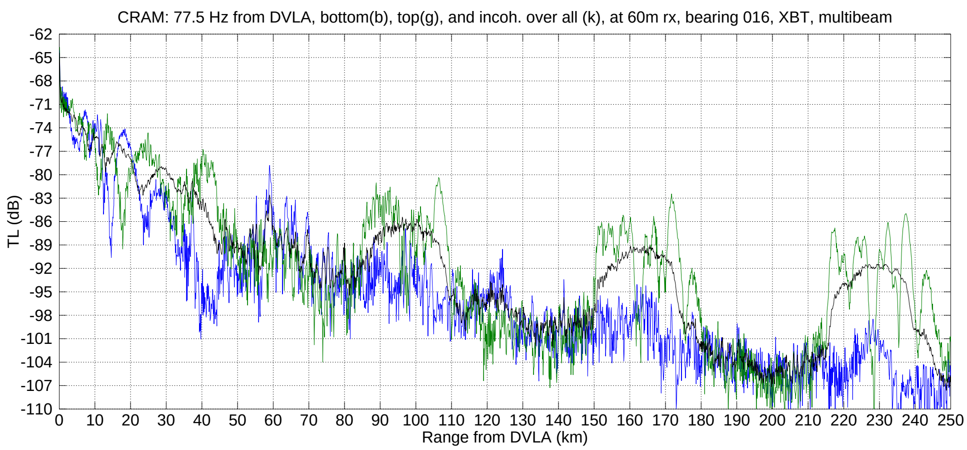


Figure 21 Transmission Loss Versus Range for the 250km Long Line
Transmission loss versus range for the 250km long line using PE-CRAM.

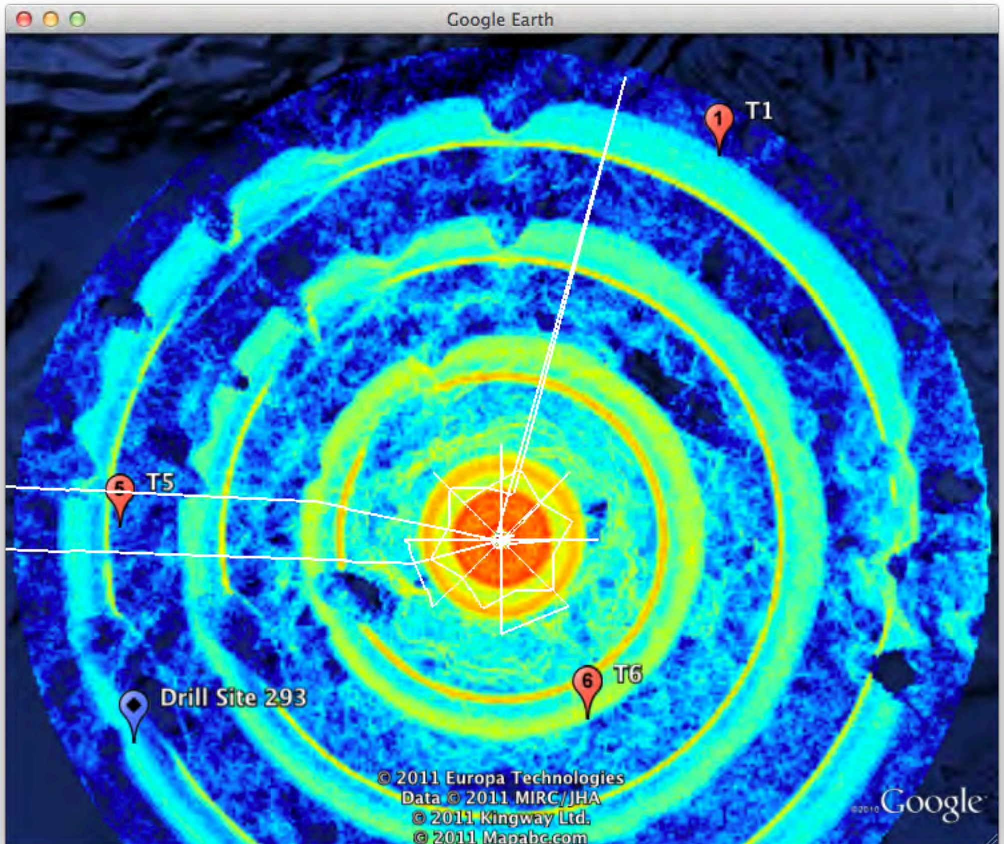


Figure 22 Plan View of Transmission Loss Around the O-DVLA
This figure shows TL computed using the CRAM PE model out to 260 km from the top phone of the Deep DVLA, incoherently averaged over three frequencies (77.5, 155, and 310 Hz) and the range of source depths (50-100m) possible with the tow cable configuration. Colormap limits of the image are 105 to 69 dB relative to TL at one meter. The World Ocean Atlas 2009 and ETOPO1 one-minute bathymetry are used as environmental inputs.

8. Hydrophone Modules

Hydrophone deployment:
Please see the attached xls file for more specific details on the deployment of the HMs on the DVLA.
1 DSTAR on DVLA
15 Hydrophone Modules on DVLA
These Hydrophone Modules were configured to take commands from the DSTAR according to the DSTAR schedule.

3 Hydrophone Modules on OBSs (1/ea on OBS4, OBS3, and OBS1)
Hydrophones on the OBSs were configured
Acoustic Sampling
Sample Rate: 1953.1250Hz, Warmup: 400 sec, Start time: 120 11:40:00, Number of samples: 6994100, Duration: 624,
NAV Sampling
Start Time 49min 55sec past hour, Number of samples: 585930,
Thermistor sample, Start 9 min 00 sec past hour, 12 samples/hour,
Time latch task disabled.

Table 9: Hydrophone Module Summary

Device Name	SN	Date/Time Deployed (GMT)	Longitude	Latitude	Configuration	Deployed as part of:	Notes:
Hydrophone Module	**HM167**	120 2021	125 65.163E	21 19.558N	Acoustic Sample Rate: 1953.1250Hz, Warmup: 400 sec, Start time: 120 11:40:00, Number of samples: 6994100, Duration: 624, NAV Sampling: Start Time 49min 55sec past hour, Number of samples: 585930, Therm sample, Start 9 min 00 sec past hour, 12 samples/hour, Time latch task disabled.	OBS-4	Deliberately set to record longer than anticipated to be deployed.
Hydrophone Module	**HM168**	120 2150	125 56.646E	21 18.351N	Acoustic Sample Rate: 1953.1250Hz, Warmup: 400 sec, Start time: 120 11:40:00, Number of samples: 6994100, Duration: 624, NAV Sampling: Start Time 49min 55sec past hour, Number of samples: 585930, Therm sample, Start 9 min 00 sec past hour, 12 samples/hour, Time latch task disabled.	OBS-3	Deliberately set to record longer than anticipated to be deployed.

Device Name	SN	Date/Time Deployed (GMT)	Longitude	Latitude	Configuration	Deployed as part of:	Notes:
Hydrophone Module	**HM169**	121 0019	125 56.325E	21 20.637N	Acoustic Sample Rate: 1953.1250Hz, Warmup: 400 sec, Start time: 120 11:40:00, Number of samples: 6994100, Duration: 624, NAV Sampling: Start Time 49min 55sec past hour, Number of samples: 585930, Therm sample, Start 9 min 00 sec past hour, 12 samples/hour, Time latch task disabled.	OBS-1	Deliberately set to record longer than anticipated to be deployed. The Hydrophone tube on this HM appears to have been bumped. Resulted in deformation of the screw hole on one side and a looser fit of the tube on the HM. May create artifacts in data.
DSTAR	**106**	12 April 2011 00:39	125 56.537E	21 19.519N	Controller for DVLA. Deployed at top of 1km cable.	DVLA	
Hydrophone Module	**HM011**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 159m from DSTAR	DVLA	
Hydrophone Module	**HM007**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 120m from previous HM	DVLA	
Hydrophone Module	**HM008**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 120m from previous HM.	DVLA	

Device Name	SN	Date/Time Deployed (GMT)	Longitude	Latitude	Configuration	Deployed as part of:	Notes:
Hydrophone Module	**HM009**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 120m from previous HM.	DVLA	
Hydrophone Module	**HM010**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 120m from previous HM.	DVLA	
Hydrophone Module	**HM040**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 120m from previous HM.	DVLA	
Hydrophone Module	**HM053**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 120m from previous HM.	DVLA	
Hydrophone Module	**HM060**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 50m from previous HM.	DVLA	This HM lost a screw from the hydrophone tube at some point in the deployment, this may cause noise from the tube rattling.
Hydrophone Module	**HM061**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 10m from previous HM	DVLA	

Device Name	SN	Date/Time Deployed (GMT)	Longitude	Latitude	Configuration	Deployed as part of:	Notes:
Hydrophone Module	**HM075**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 10m from previous HM	DVLA	
Hydrophone Module	**HM101**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 10m from previous HM	DVLA	
Hydrophone Module	**HM120**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 10m from previous HM	DVLA	
Hydrophone Module	**HM136**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 10m from previous HM	DVLA	
Hydrophone Module	**HM155**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 10m from previous HM	DVLA	
Hydrophone Module	**HM163**	12 April 2011 00:39	125 56.537E	21 19.519N	Controlled by DSTAR schedule. Deployed 10m from previous HM	DVLA	

9. Source Frequency Response and Linearity

Frequency response of the J15 was measured by an assortment of related long-period linear chirps, all of which started at 40 Hz. For logistical reasons the same signal with the same gain settings was not used at the beginning and end of the test. In each case the 40-500 Hz band was isolated. A full-timeseries FFT was performed and the output was incoherently averaged over adjacent 1 Hz-wide subbands, giving resistance to scalloping loss. This procedure was repeated on the measured power amplifier current and voltage signals, to ensure that structure in the output was unique to the J15-H91 system and not introduced by the power amplifier.

Results indicate that a broad peak followed by a series of nulls existed in the region between 100 and 200 Hz, with a relatively flat response above this range. No flat region existed below the initial broad peak. Strength of the peak relative to the higher-frequency flat region varied between 9 to 12 dB. The entire structure shifted slightly as a function of depth, as well as from the beginning to the end of the test with varying J15 configuration.

Linearity (distortion) of the J15 was quantified by comparing energy at the fundamental frequency to energy in the first harmonic (twice the fundamental). A high ratio here means a very linear, undistorted signal. Energy in the fundamental and first harmonic was collected over a 20 dB range of input current. The resulting ratio is plotted versus the energy in the fundamental, in a scatter plot with multiple discrete frequencies, spanning the octave of greatest variability in the previously observed J15 frequency response.

Results indicate that in the initial J15 configuration, linearity was poor at low frequencies, and better at higher frequencies. At the end of the cruise the test was repeated, giving better results at lower frequencies, roughly the same in the middle range, and a very poor high frequency result. A swept-frequency test at the same station indicated that the highest test tone had landed in a very deep null which had previously been at a higher frequency.

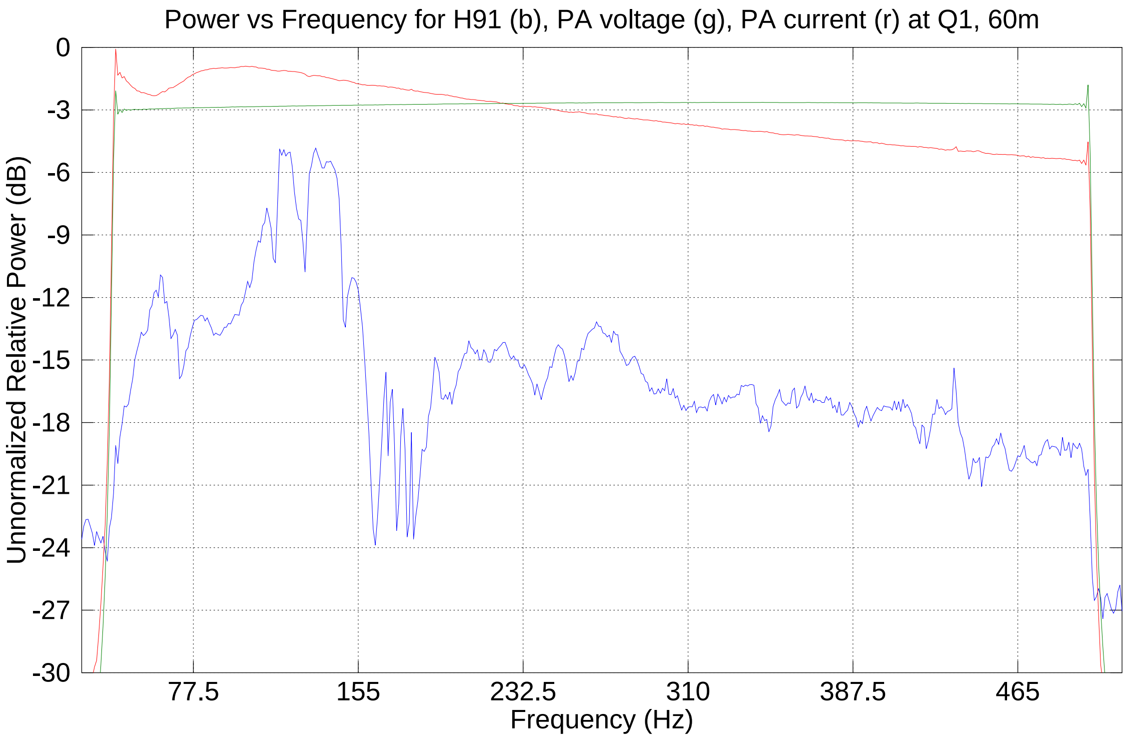


Figure 23a Source Frequency Response at Q1 - 60m - S/N 11 as Delivered
Source frequency response at Q1 - 60m - S/N 11 as delivered.

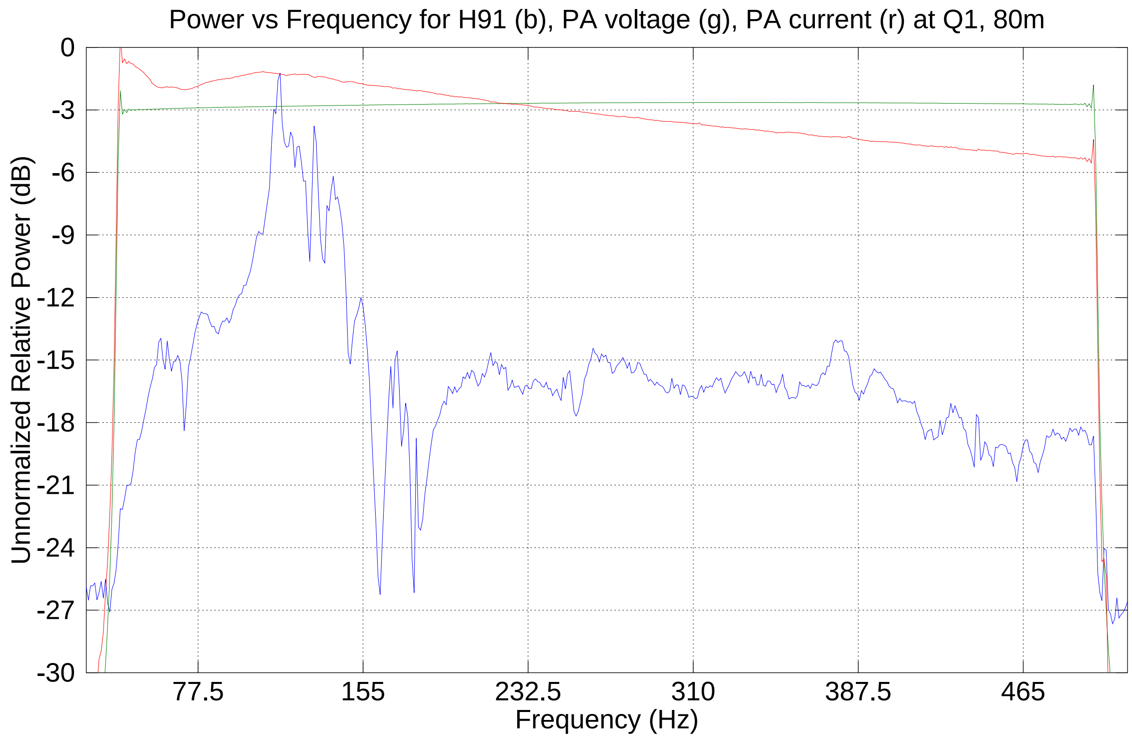


Figure 23b Source Frequency Response at Q1 - 80m - S/N 11 as Delivered
Source frequency response at Q1 - 80m - S/N 11 as delivered.

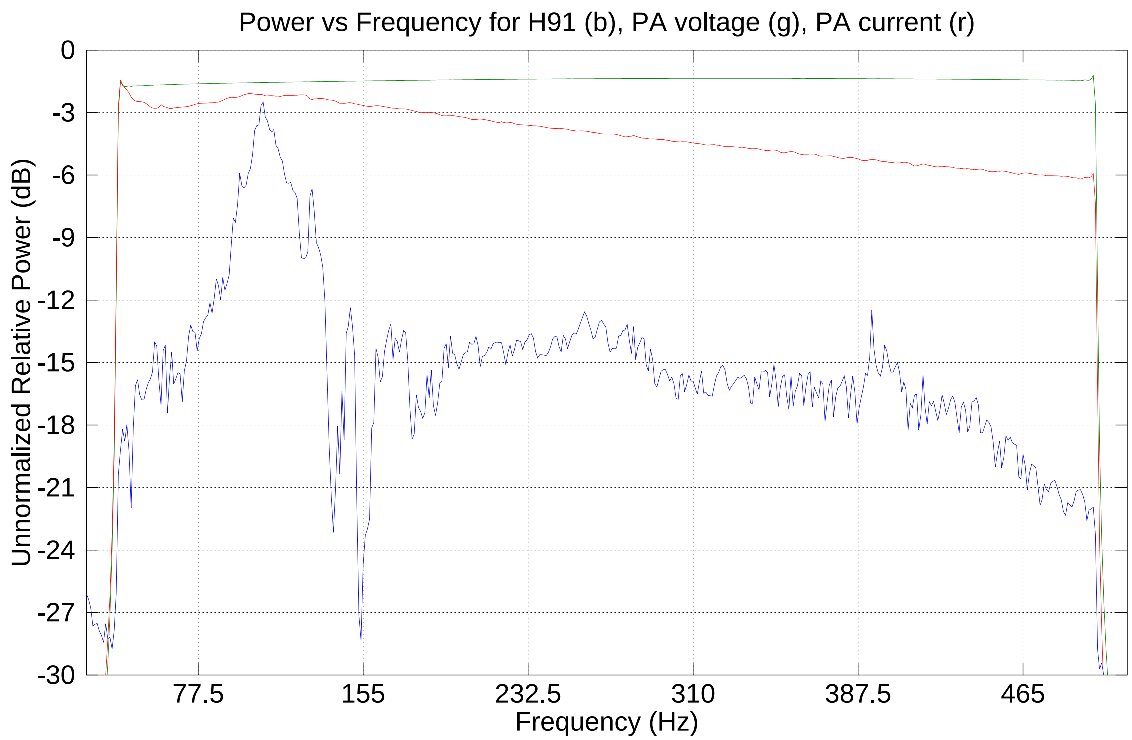


Figure 23c Source Frequency Response at TNE - 73m - S/N 11 With Replaced Transducer
Source frequency response at TNE - 73m - S/N 11 with replaced transducer.

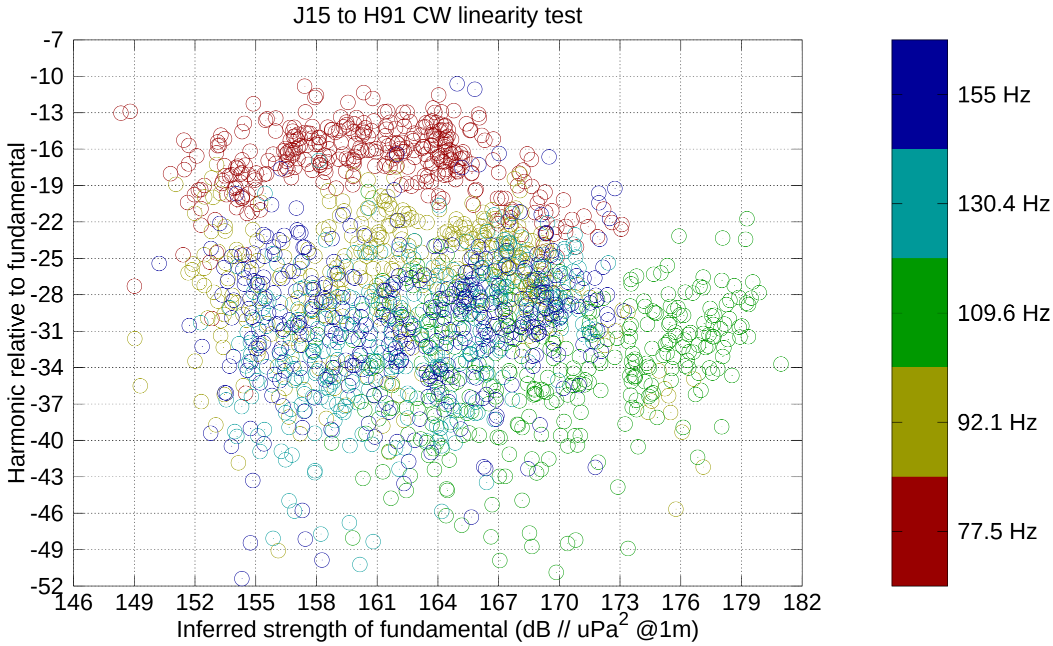


Figure 24a Source Linearity Test at Q1 - 60m - S/N 11 as Delivered
Source linearity test at Q1 - 60m - S/N 11 as delivered

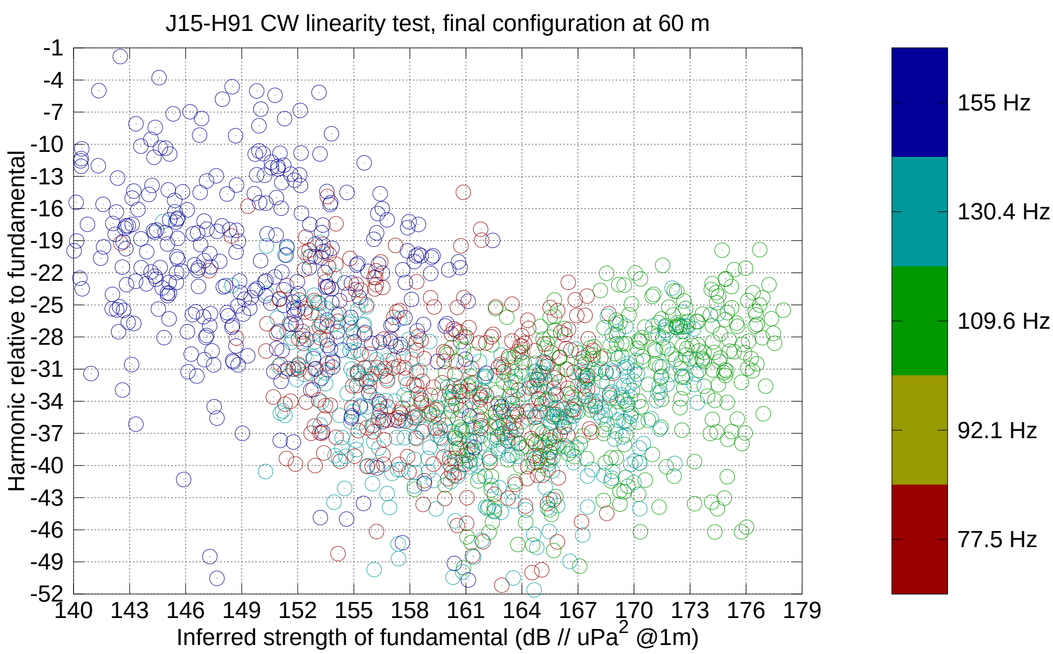


Figure 24b Source Linearity Test at TNE - 73m - S/N 11 with Replaced Transducer
Source linearity test at TNE - 73m - S/N 11 with replaced transducer

10. Quick Look Analysis

Data from the SIO hydrophone modules and from the OBSIP OBSs was not available in exchange format when we left the ship on May 16. The data from 16 of the 18 hydrophone modules was received at WHOI on June 3, 2011. Data from HM 053 (at 132m off the bottom) was sent from Scripps on June 21. HM075 (at 62m off the bottom) essentially failed. The OBSIP OBS data arrived at WHOI on June 17. OBS #2, the short period OBS east of the O-DVLA, flooded and no useful data is available.

All sensors that acquired some data appear to have a full complement of data. The hydrophone modules (HM) on the DVLA started recording acoustic data at 1607Z on JD108 and stopped recording at 1601Z on JD132 (24 days). HM data is exchanged in hour-long files. There are short gaps in the available HM acoustic data around 50 minutes past the even hour. The OBSs started recording continuous seismic data shortly after deployment, between 2000Z on JD120 to 0030Z on JD 121, and stopped recording on recovery, between 1615Z on JD132 and 1030Z on JD 134 (about 12.5days). OBS data is exchanged in day files. The hydrophone modules on the OBSs also recorded from deployment to recovery (about 12.5days) but had hour-long files with short gaps similar to the HMs on the DVLA. The transmission program started at 0238Z on JD121 and finished at 1130Z on JD132 (about 11.5days).

Because data from the deployed receivers was not available until after the cruise, during the shooting program we had no idea whether the J15-3 was transmitting loudly enough or faithfully enough to excite arrivals of interest on the deep elements of the DVLA and the OBSs. Furthermore since many receivers on NPAL04 were system noise limited (electronic noise in the acquisition system was louder than the ambient noise) we wanted to check spectra on the various receivers. So in the quick-look analysis we focused on three things: a) time compressions of the data for the transect from 50km SW to 50km NE of the DVLA, b) any evidence for Deep Seafloor Arrivals, and c) spectral analysis for just a few minutes of data on selected receivers.

10a. Time-Compressed Data for the SW-NE Transect

On the SW-NE transect (Event #7, Figure 11g) the target tow depth was 60m and we transmitted "Multi-Frequency M-sequence, Short-Range Tows" (77.5, 155 and 310Hz, see Section 6) at 2knots. Time compressions were carried out using the prescribed format that was sent to the J15-3 controller. (Although we acquired all transmissions on a monitor hydrophone strapped to the J15-3, we did not initially use this source monitor data for the time compressions.) A range of Doppler velocities were used for the time compressions and we selected the velocity that resulted in the largest amplitude peak for each trace. Examples of the raw time compressions for one five minute interval on the hydrophone module on the North OBS are given in Figure 25.

Four M-sequences were transmitted at each frequency. Single M-sequences have durations of 26.4sec, 26.4sec and 13.2sec respectively for 77.5, 155 and 310Hz. Because peaks can result

from processing just a portion of an M-sequence five peaks typically appear in the time-compressed traces. The first and last of the five peaks correspond to partial M-sequence transmissions. In general only the middle three peaks correspond to complete transmissions and have meaningful amplitudes.

To study SNR we took the largest amplitude peak on the time compressed trace as signal and then computed the RMS level of 1sec of noise either 2sec before or 20sec after the peak arrival time. Plotting these signal, noise, and SNR levels as a function of range gives a quick overview of the performance of the various sensors for this one line (Figure 26).

Figure 27 compares SNRs as a function of range for the SW-NE line for the hydrophone module on the North OBS and the shallowest hydrophone module on the O-DVLA (852m above the seafloor). It is interesting that at 77.5Hz the SNR is higher by 6dB or so at the seafloor than 852 above the seafloor for ranges out 20km. It is also interesting that there is adequate SNR at ranges beyond 45km to the South and North on the seafloor OBS. The low SNR on the seafloor HM from 35 to 45km to the North is a consequence of higher than usual noise levels (see Figure 26a).

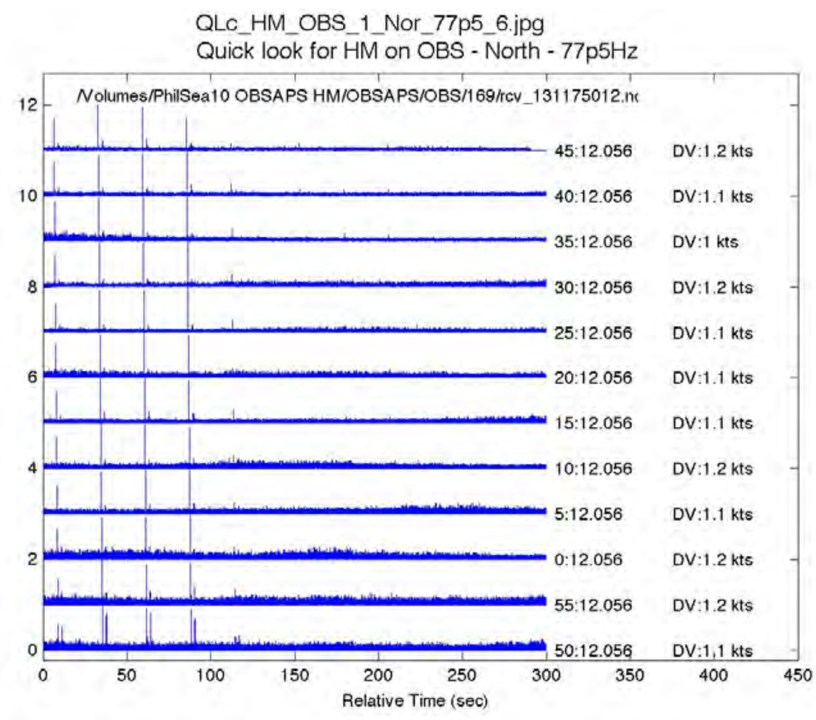


Figure 25a 77.5Hz Time-Compressions on the Hydrophone Module Strapped to the North OBS

The absolute amplitude of the raw time compressions at 77.5Hz is plotted for an hour of data on the hydrophone module strapped to the North OBS. The ranges (to the North OBS) varied from 32.6km (start of bottom trace) to 28.0km (end of top trace) on the line SW of the O-DVLA. There is a strong doublet of arrivals, reminiscent of DSFAs, on the bottom trace (see Section 10b).

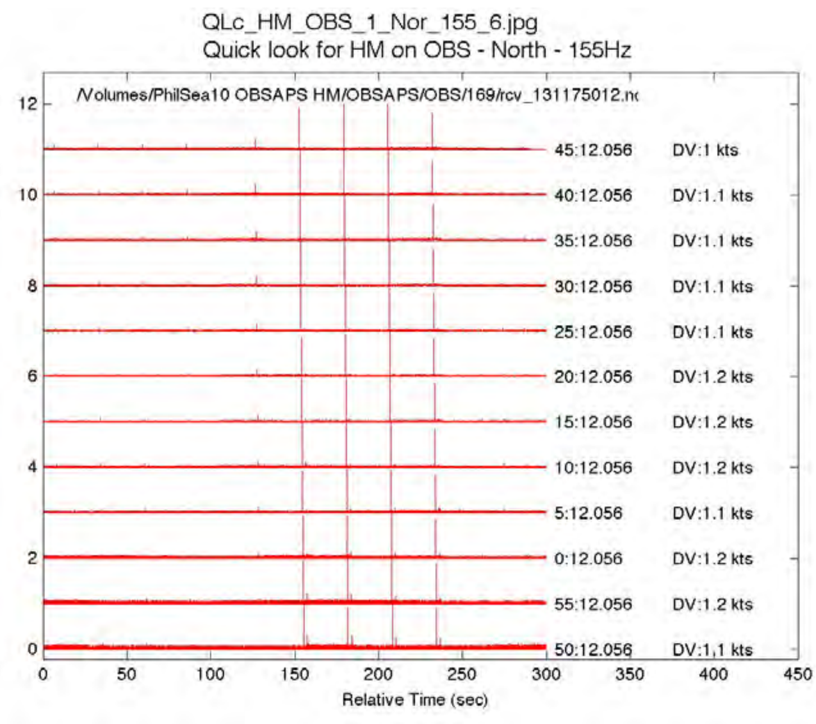


Figure 25b 155Hz Time-Compressions on the Hydrophone Module Strapped to the North OBS
Same as Figure 25a but for the 155Hz M-sequence.

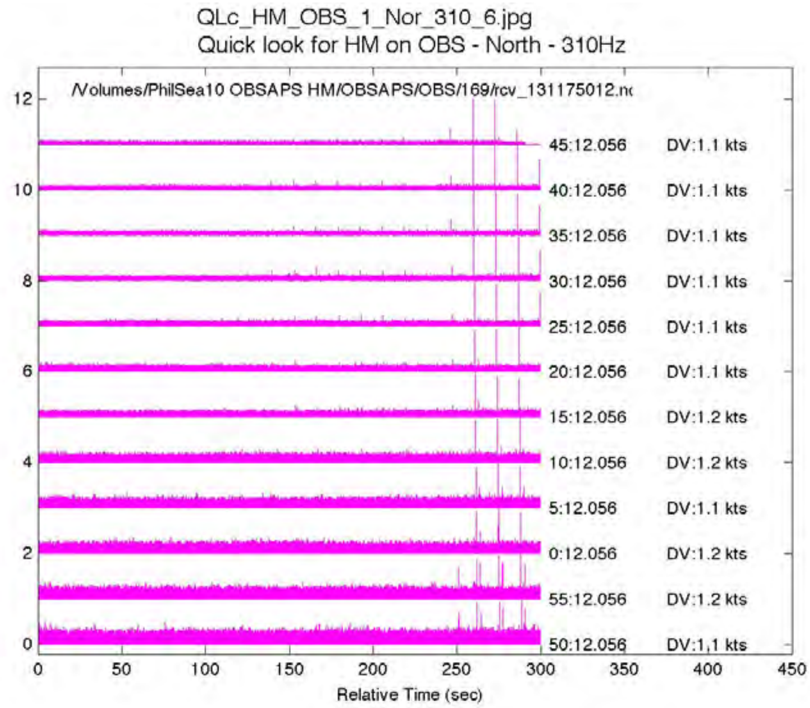


Figure 25c 310Hz Time-Compressions on the Hydrophone Module Strapped to the North OBS
Same as Figure 25a but for the 310Hz M-sequence.

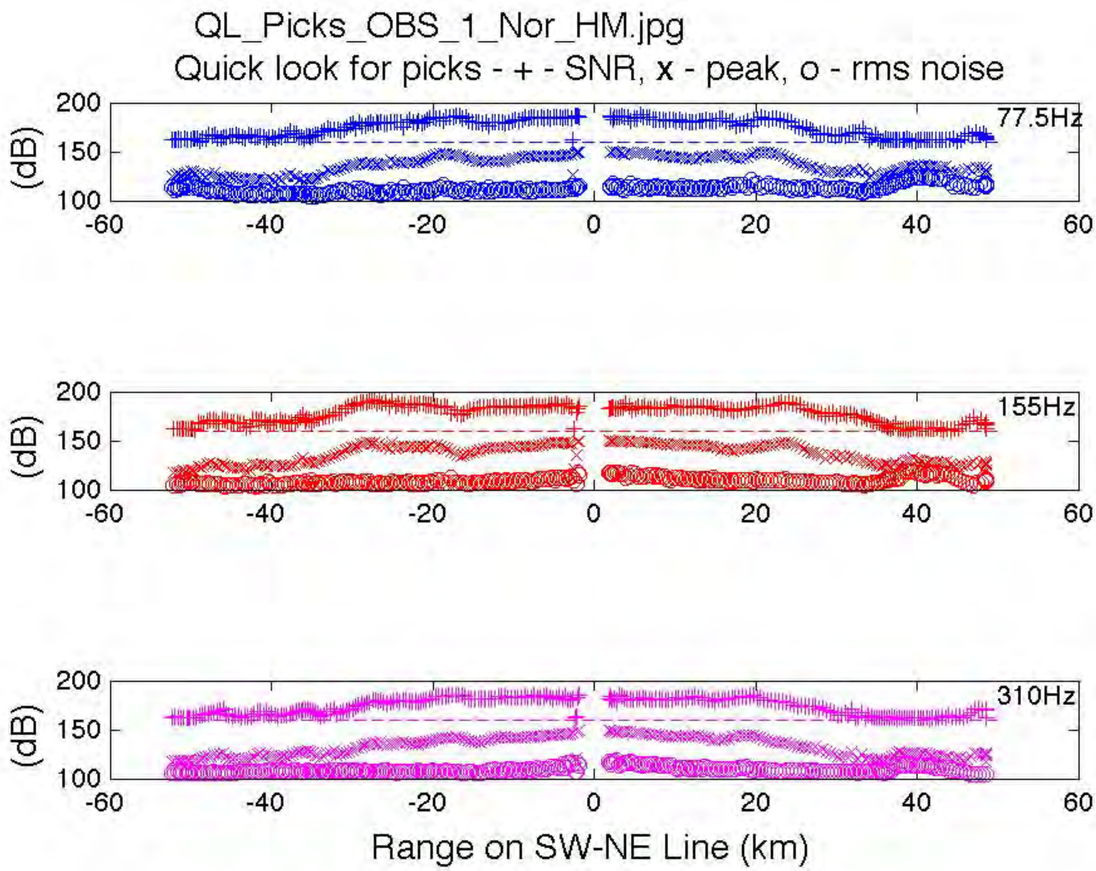


Figure 26a SNR Summary for the Hydrophone Module Strapped to the North OBS
Peak signal (x), RMS noise (o) and SNR (+) are shown as a function of range along the SW-NE line for 77.5, 155, and 310Hz for the hydrophone module strapped to the North OBS (#1). The SNR is plotted above 150dB (dashed line).

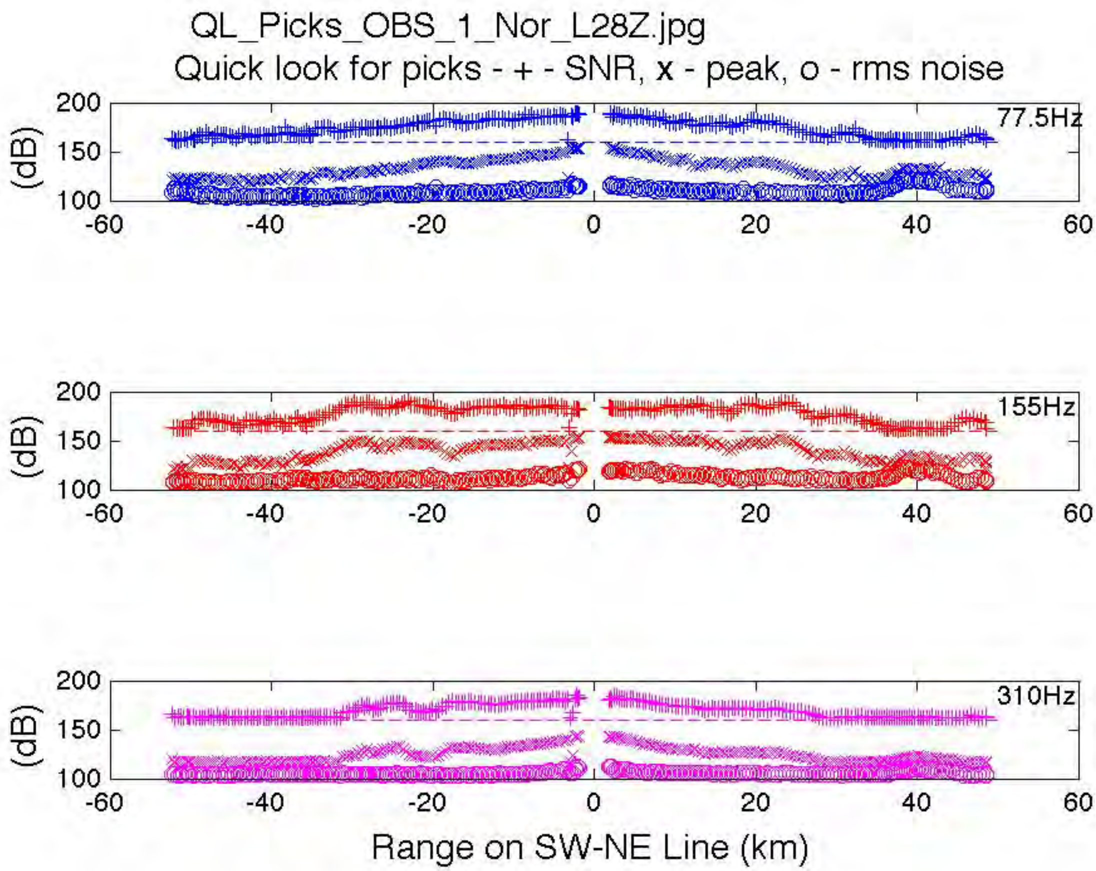


Figure 26b SNR Summary for the Vertical Geophone on the North OBS
As Figure 26a for the vertical component geophone on the North OBS (#1).

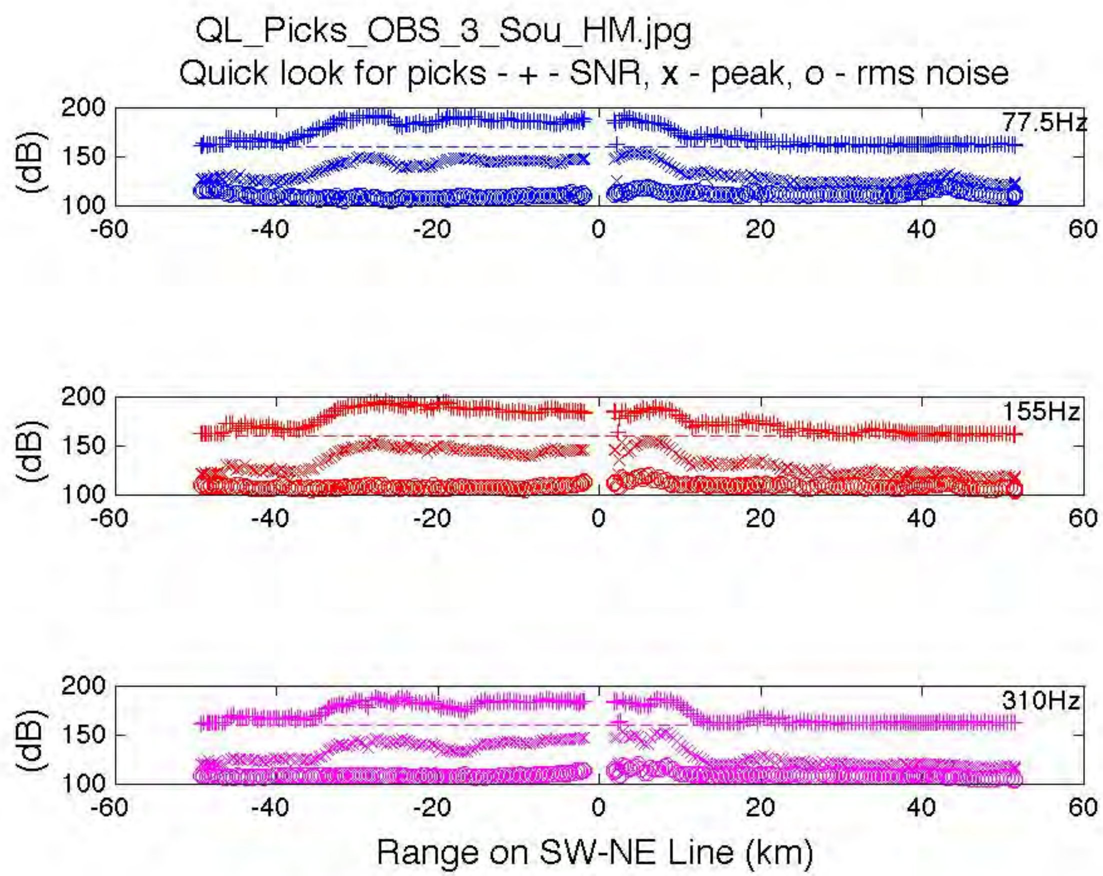


Figure 26c SNR Summary for the Hydrophone Module Strapped to the South OBS
As Figure 26a for the hydrophone module on the South OBS (#3). Transmissions from the northeast are blocked by a bathymetric high (see Figure 8).

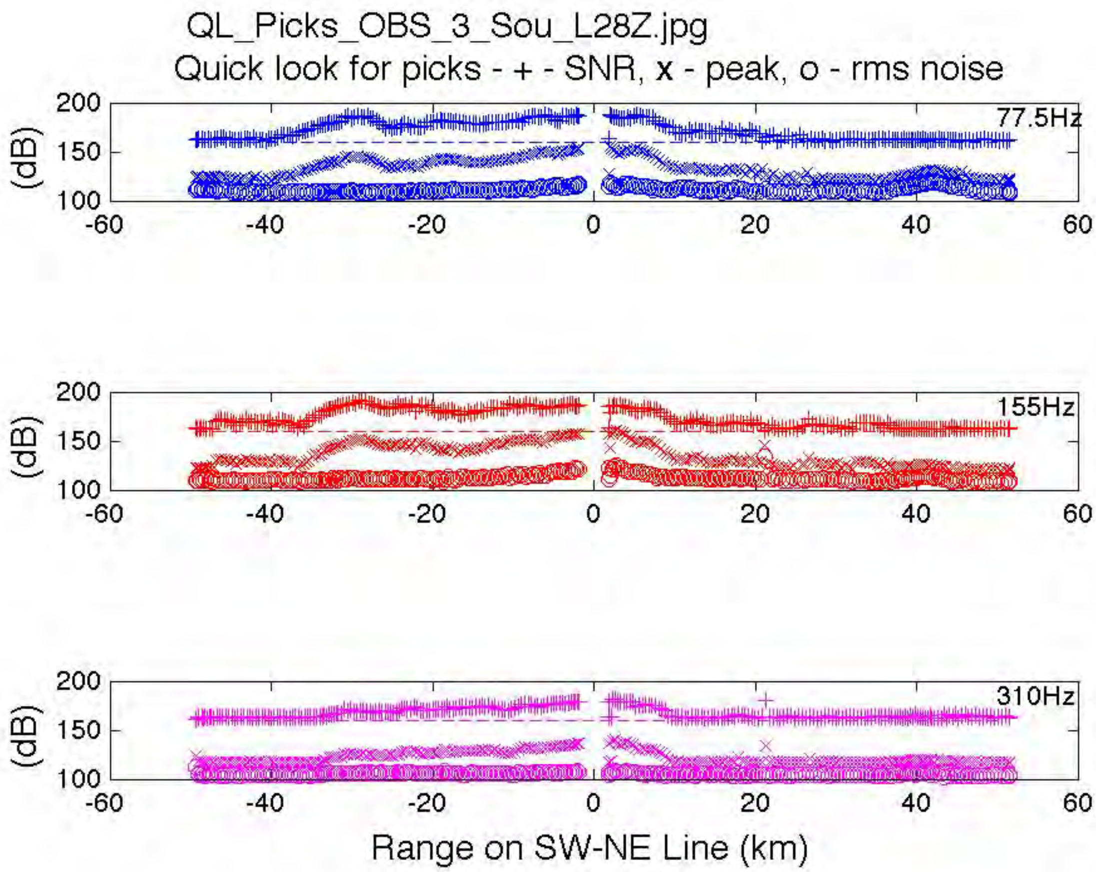


Figure 26d SNR Summary for the Vertical Geophone on the South OBS
As Figure 26a for the vertical component geophone on the South OBS (#3).

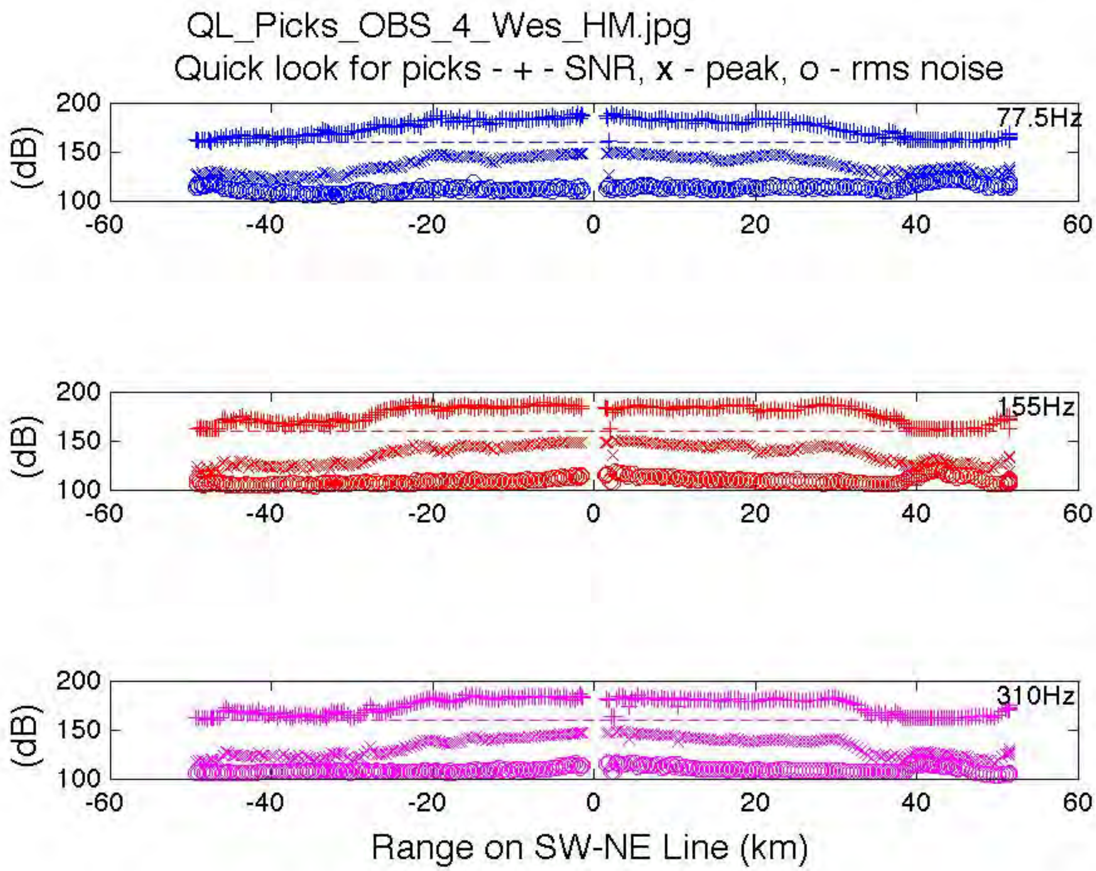


Figure 26e SNR Summary for the Hydrophone Module Strapped to the West OBS
As Figure 26a for the hydrophone module on the West OBS (#4).

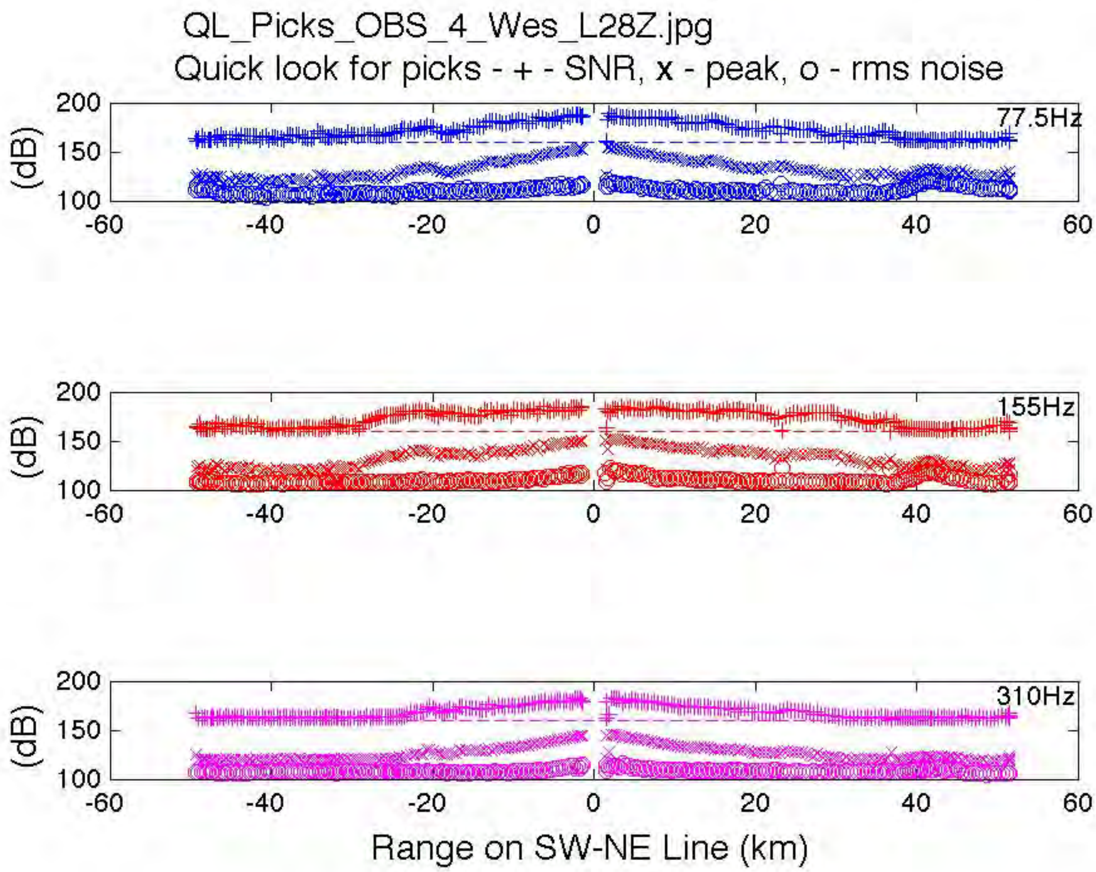


Figure 26f SNR Summary for the Vertical Geophone on the West OBS
As Figure 26a for the vertical component geophone on the West OBS (#4).

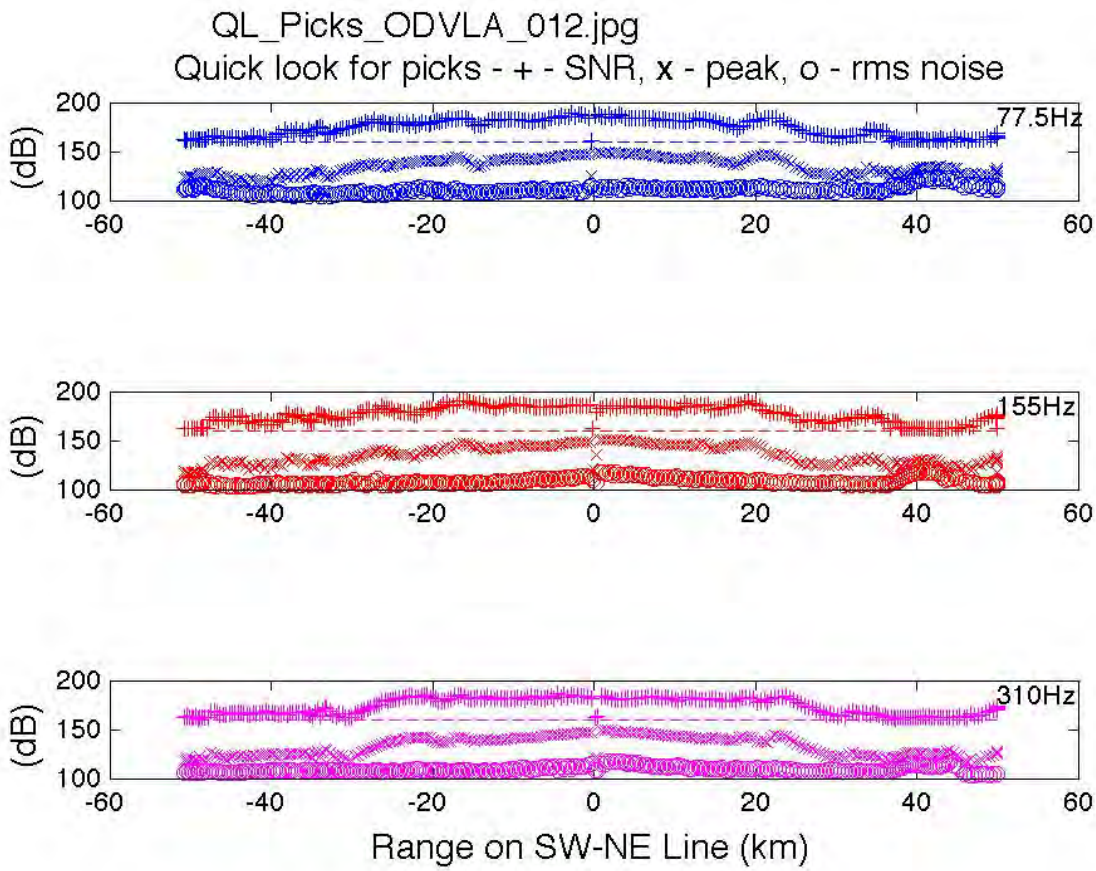


Figure 26g SNR Summary for the Deepest Hydrophone Module on the O-DVLA
As Figure 26a for the deepest hydrophone module on the O-DVLA (12m above the seafloor).

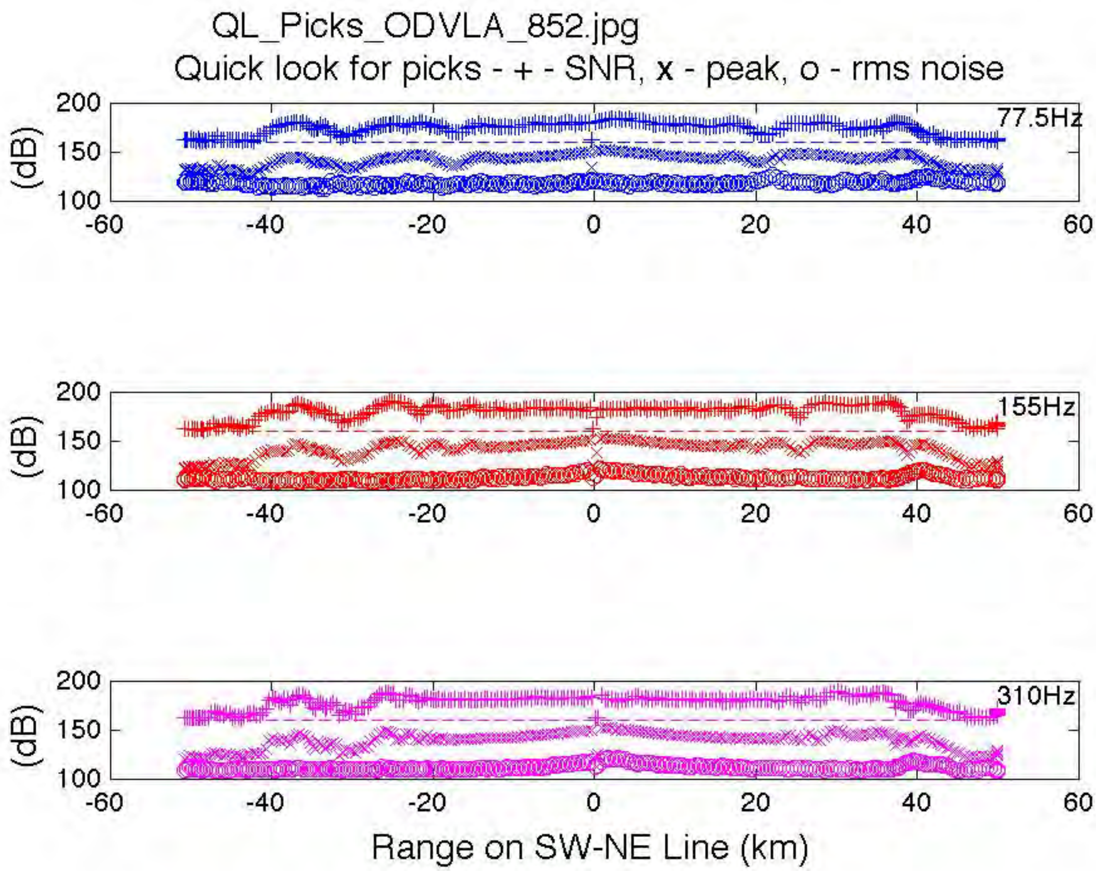


Figure 26h SNR Summary for the Shallowest Hydrophone Module on the O-DVLA
As Figure 26a for the shallowest hydrophone module on the O-DVLA (852m above the seafloor).

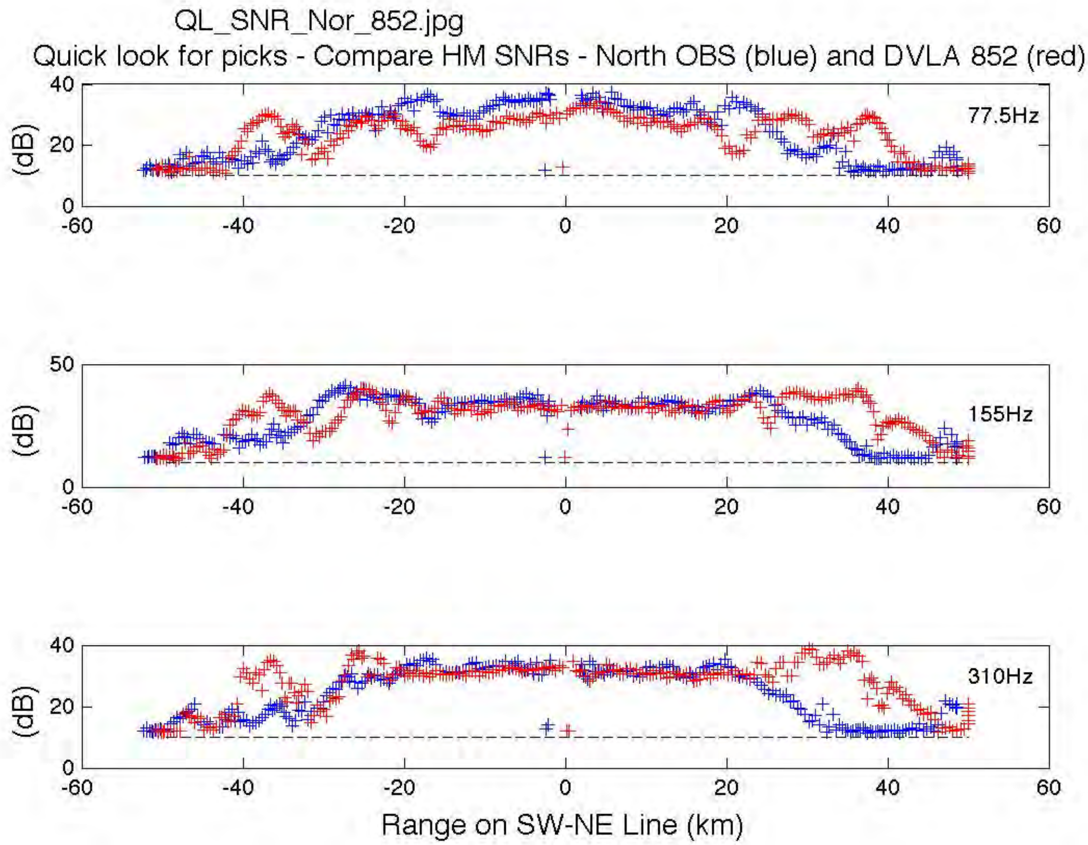


Figure 27 SNR Comparison for the Shallowest HM and the HM on the North OBS
SNRs as a function of range are compared between the seafloor hydrophone module (on the North OBS) and the shallowest element on the O-DVLA (at 852m above the seafloor).

10b. Evidence for Deep Seafloor Arrivals

We discuss below arrivals on three sections on the SW-NE transect where evidence for Deep Seafloor Arrivals (DSFAs) appears. For simplicity we start looking on the 77.5Hz time compressions because it was at 68.5 and 75Hz that the DSFAs were observed on NPAL04.

Generally there is only a single arrival on the shallow-most hydrophone module on the O-DVLA. We have not done careful PE modeling yet, but based on the NPAL04 experience we call this the "PE-predicted" arrival. Potential DSFA arrivals are identified by two characteristics: a) they arrive much later than the PE predicted arrival (by 2-7sec) and b) their SNR is highest on the seafloor receivers and decreases with increasing height above the seafloor.

(Note that the ranges given below correspond to the start time of the four 77.5Hz transmissions. We have not allowed for time delay within the 2min-long 77.5Hz window. The O-DVLA is on the SW-NE line but the OBS's are offset from the O-DVLA location by about 2km. So the ranges and azimuths to the OBSs and the O-DVLA HMs are not the same. In the multiple receivers plots below time shifts have been applied to align the "PE Predicted" arrival, usually the largest and most distinct event, across all of the receivers. The shifts varied between minus and plus one second.)

i) About 30km to the Southwest on the North OBS

Figure 28a shows the time-compressed traces for hour 18 on JD131 on the southwest line for the vertical component geophone on the North OBS. Ranges varied from 31.8km (at the bottom) to 27.7km (at the top). There appear to be at least two and often three arrivals throughout this period. We chose to look at two events in more detail: Example # 1 - transmission number 3 (at about 75sec) on the 0.0minute trace, and Example #2 - transmission number 4 (at about 100sec) on the 40minute trace, in Figures 28b and 28c respectively. Both examples show a clear doublet event - two strong arrivals separated by about 3sec. The first arrival, a PE predicted arrival, is strong across all receivers. The second arrival is clearly strongest on the OBS vertical geophone and decreases in SNR with height above the seafloor. It is strange that this event is not stronger on the co-located hydrophone module. The doublet event seems to persist from at least 27.7 to 31.8km range from the North OBS to the southwest. There are also indications of other, weaker DSFAs on the OBS vertical geophone.

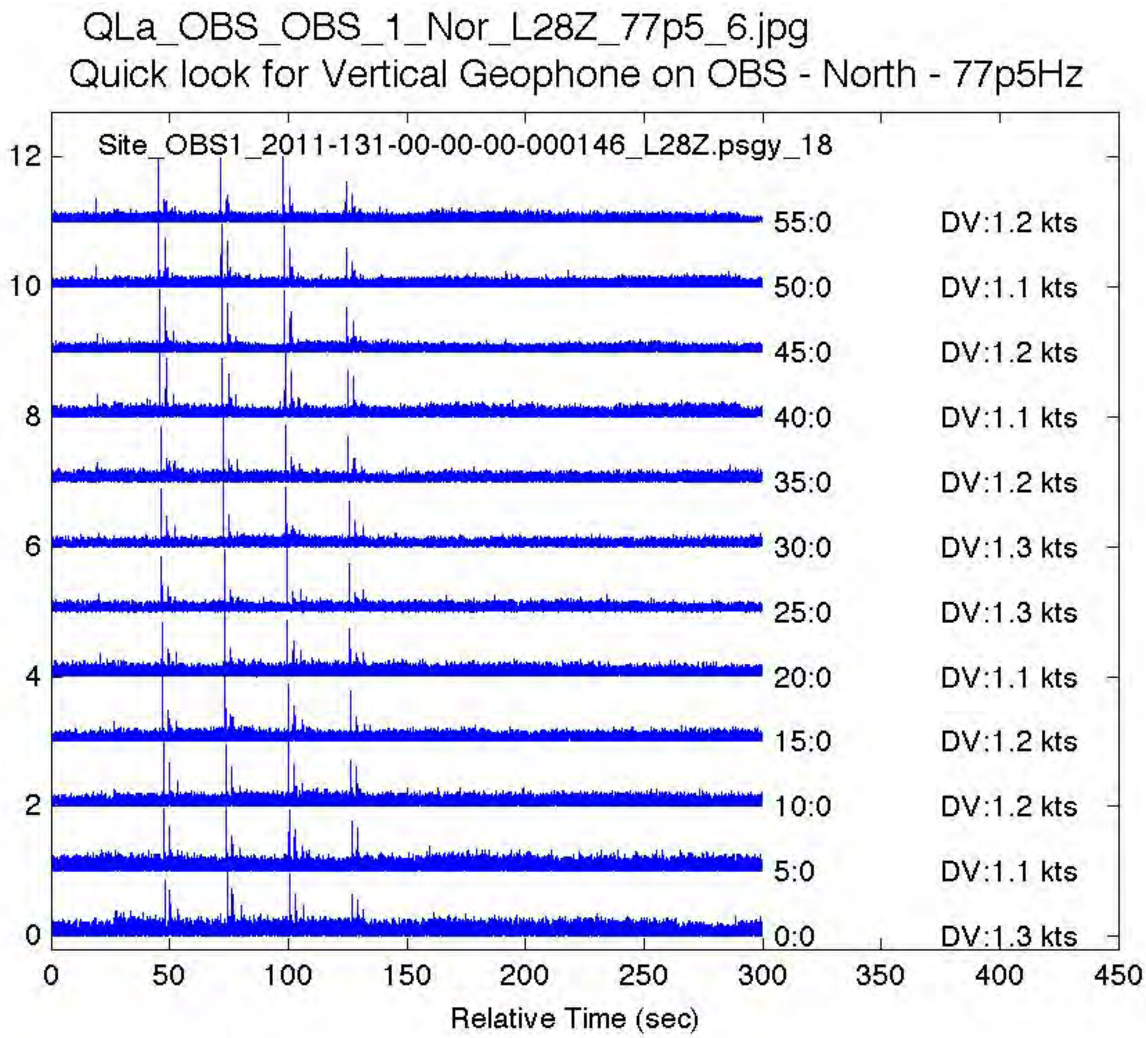


Figure 28a 77.5Hz Time-Compressions on the Vertical Geophone - North OBS - JD131 1800Z

The time-compressed traces at 77.5Hz for hour 18 on JD131 on the southwest line for the vertical component geophone on the North OBS. Ranges varied from 31.8km (at the bottom) to 27.7km (at the top). Although we transmitted only four M-sequences, because of overlapping windows we get five apparent transmissions - near 25, 50, 75, 100 and 125sec on this plot. There appear to be at least two and often three significant peaks for each M-sequence throughout this period. These traces on the vertical component can be compared with the traces for the co-located hydrophone module in Figure 25a. We chose to look at two events in more detail: Example # 1 - transmission number 3 (at about 75sec) on the 0minute trace, and Example #2 - transmission number 4 (at about 100sec) on the 40minute trace.

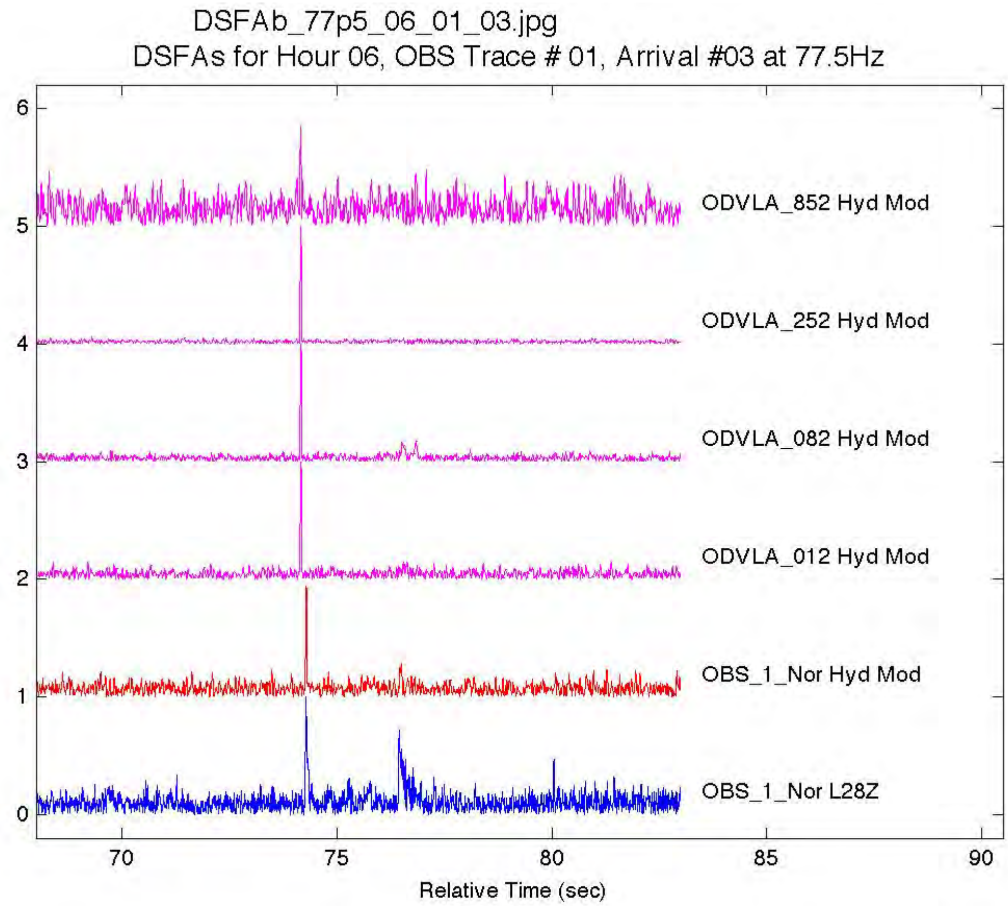


Figure 28b DSFA Example #1

Here we compare receptions for a single 77.5Hz M-sequence on six OBSAPS receivers: (from bottom to top) the vertical geophone on the North OBS (blue), the hydrophone module on the North OBS (red), and the hydrophone modules on the O-DVLA at 12, 82, 252 and 852m above the seafloor (magenta). This was the third transmission (of five) on the 131JD1800 trace in Figure 28a. The range to the North OBS (bottom two traces) was 31.4km and the range to the O-DVLA (top four traces) was 30.3km. We call the large peak near 74sec the "PE predicted" arrival because it is consistently a large arrival across all of the receivers. The strong arrival about 3sec later on the vertical geophone on the OBS is a classic DSFA, although it is strange that this arrival is so weak on the co-located hydrophone module. There is a weak indication of this arrival on the O-DVLA up to at least 82m above the seafloor. There is also a weak indication of second DSFA on the geophone channel near 80sec.

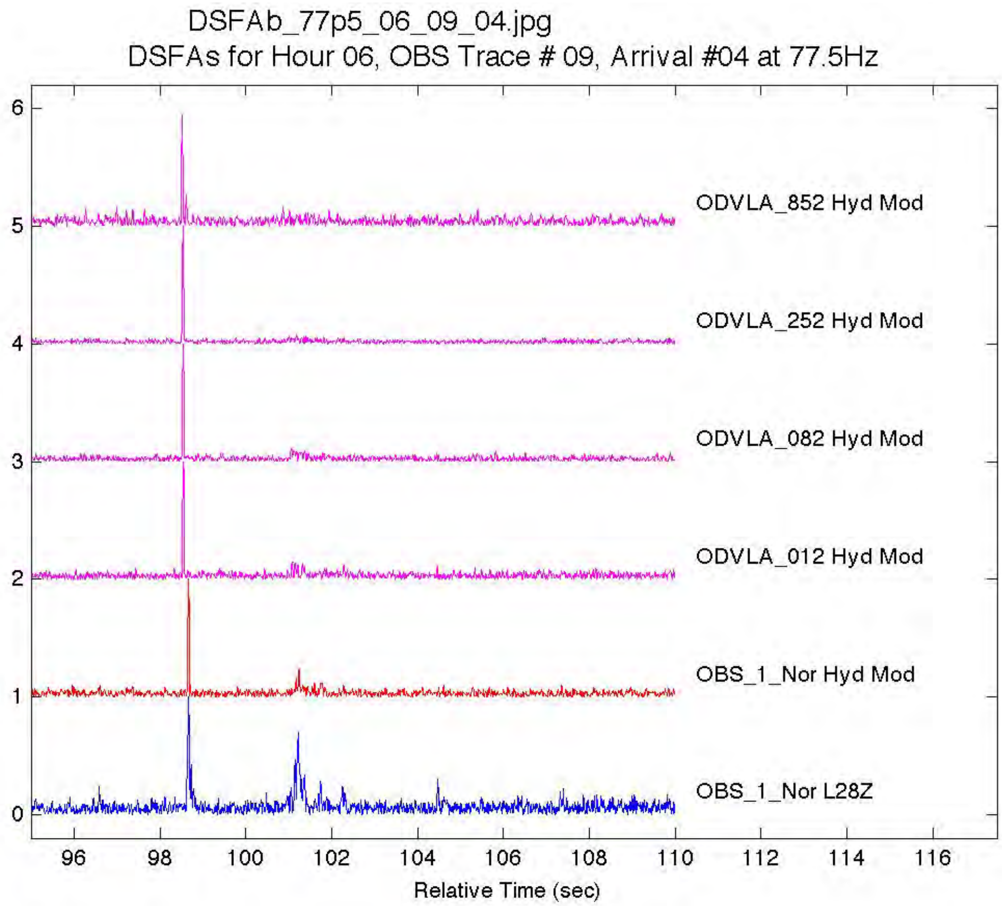


Figure 28c DSFA Example #2

This is the same format as Figure 28b for the fourth transmission (of five) on the 131JD1840 trace in Figure 28a. The range to the North OBS (bottom two traces) was 28.7km and the range to the O-DVLA (top four traces) was 27.2km. We call the large peak near 98.5sec the "PE predicted" arrival because it is consistently a large arrival across all of the receivers. The strong arrival about 3sec later on the vertical geophone on the OBS is a classic DSFA, although it is strange that this arrival is so weak on the co-located hydrophone module. This event is followed within a second by two weaker events. There is a weak indication of this arrival on the O-DVLA up to at least 82m above the seafloor. There is also a weak indication of a second DSFA on the geophone channel near 104.5sec (and possibly 107.5sec). There may also be a weak precursory event near 96.5sec. The doublet event (98.5 and 101.5 sec) seems to persist from at least 27.7 to 31.8km range from the North OBS.

ii) About 30km to the Northeast on the North OBS

The next set of examples shows a transition with range where the earlier arrival in a "three-second doublet" on the OBS fades as the later arrival grows. Figure 29a shows the time-compressed traces for hour 6 on JD132 on the northeast line for the vertical component geophone on the North OBS. Ranges varied from 27.5km (at the bottom) to 32.4km (at the top). We chose to look at three events in more detail: Example # 3 - transmission number 4 (at about 100sec) on the 0.0minute trace, Example #4 - transmission number 4 (at about 100sec) on the 25minute trace, and Example #5 - transmission number 4 (at about 100sec) on the 40minute trace, in Figures 29b, 29c and 29d respectively.

All three examples show the classic "three-second doublet" but the relative amplitude of the two arrivals in the doublet changes with range. Example #3 at 27.5 & 28.9km range has the same appearance as Examples 1 & 2. The first arrival, a PE predicted arrival, is strong across all receivers. The second arrival is clearly strongest on the OBS vertical geophone, but it is still less than the PE predicted arrival, and decreases in SNR with height above the seafloor. The shallowest one or two hydrophone module traces only show the PE predicted arrival.

Example #4, just 2km away, shows the PE predicted arrival decaying with depth towards the seafloor while the DSFA arrival increases with height above the seafloor. The DSFA (second) arrival is larger than the PE predicted (first) arrival at the 82m trace and below. Strangely the PE predicted arrival is barely detectable on the vertical geophone but is quite strong on the co-located hydrophone module.

In Example #5 just 13km further the PE predicted arrival is undetectable on the vertical geophone. If one only had the vertical geophone (on the seafloor) and the O-DVLA module at 852m, one would assume that the single arrivals on these two sensors were the same arrival and that there must be a clock error (of about 3sec) somewhere!

The signal-to-noise studies in the previous section (Figures 26 and 27) used the peak amplitude on a trace as the signal. Here we see that the peak amplitude actually corresponds to two completely different arrival types. As one moves into the shadow zone of the PE predicted arrivals the DSFA arrivals, with a three second delay, take-over.

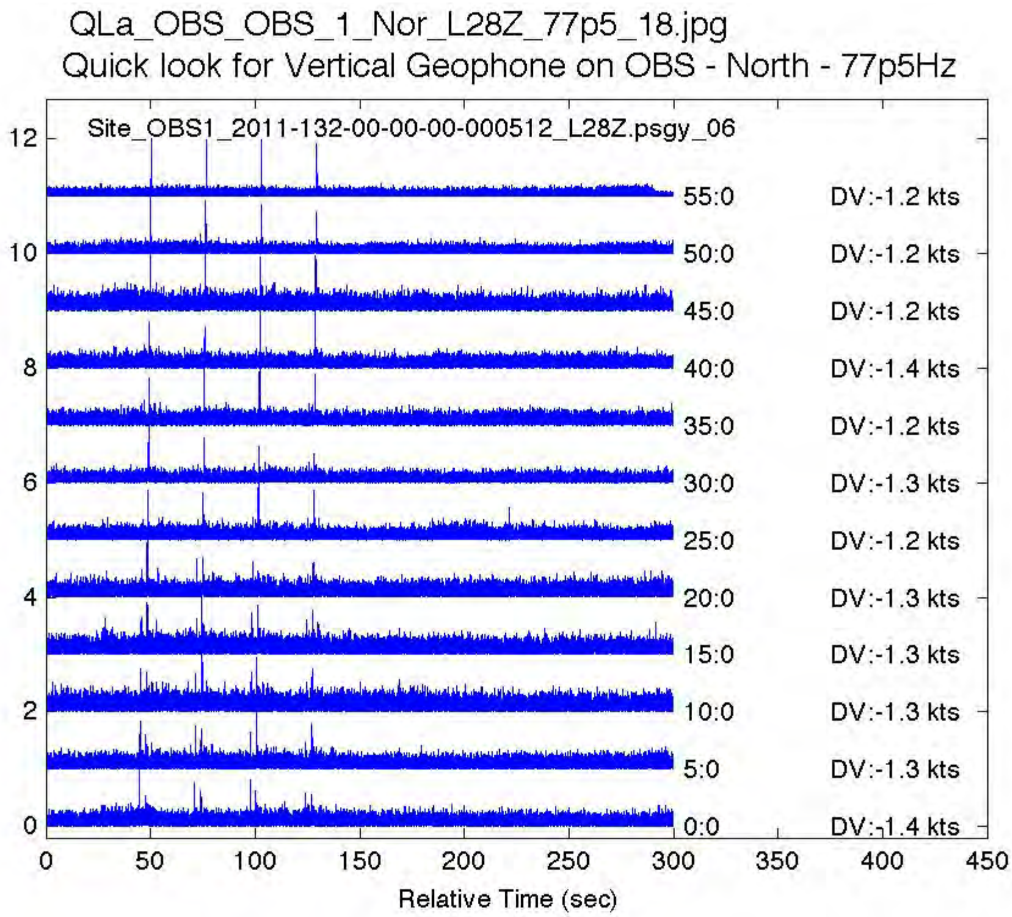


Figure 29a 77.5Hz Time-Compressions on the Vertical Geophone - North OBS - JD132 0600Z

The time-compressed traces at 77.5Hz for hour 6 on JD132 on the northeast line for the vertical component geophone on the North OBS. Ranges varied from 27.5km (at the bottom) to 32.4km (at the top). Although we transmitted only four M-sequences, because of overlapping windows we get five apparent transmissions - near 25, 50, 75, 100 and 125sec on this plot. The bottom traces show a doublet of arrivals, with the first peak of the doublet larger than the second, similar to those in Figure 28 for comparable ranges to the southwest. By the third trace from the bottom, the second peak of the doublet is larger than the first. The top traces show only single arrivals but they occur at the time of the second peak on the earlier traces. We chose to look at three events in more detail: Example # 3 - transmission number 4 (at about 100sec) on the 0.0minute trace, Example #4 - transmission number 4 (at about 100sec) on the 25minute trace, and Example #5 - transmission number 4 (at about 100sec) on the 40minute trace.

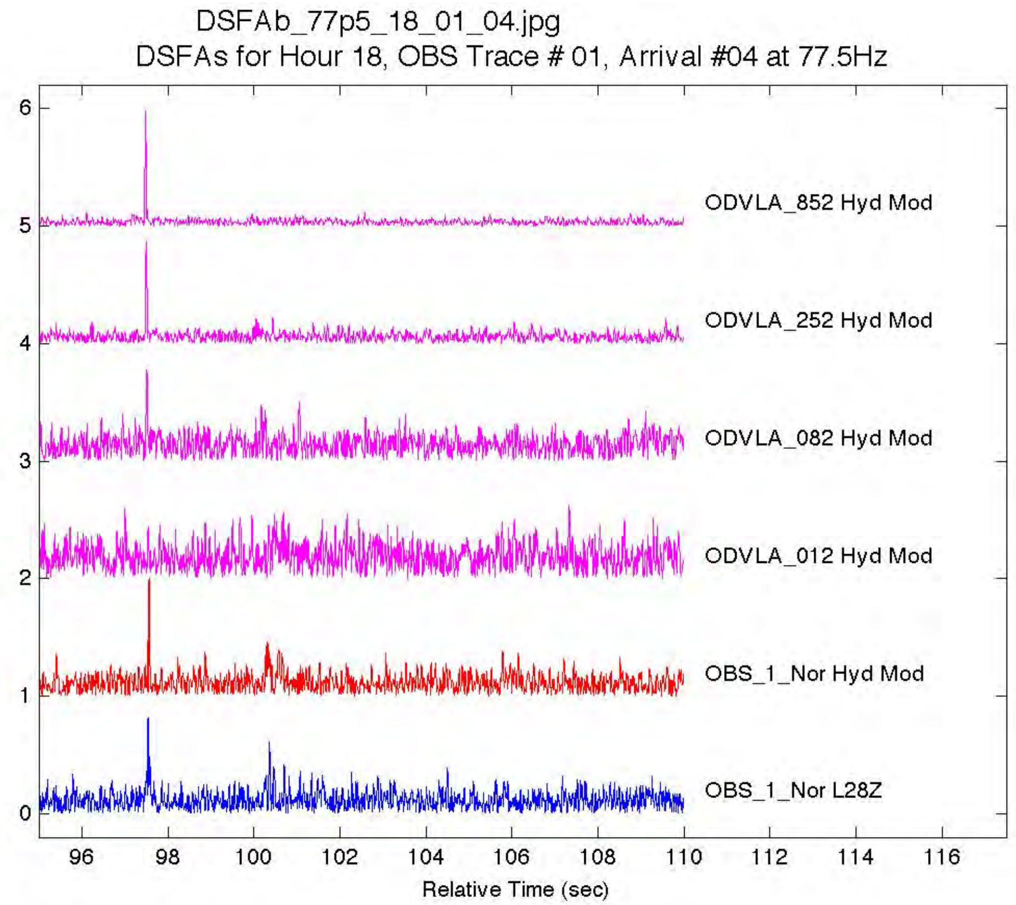


Figure 29b DSFA Example #3
This is the same format as Figure 28b for the fourth transmission (of five) on the 132JD0600 trace in Figure 29a. The range to the North OBS (bottom two traces) was 27.5km and the range to the O-DVLA (top four traces) was 28.9km. We call the large peak near 96.5sec the "PE predicted" arrival because it is consistently a large arrival across all of the receivers (not sure why it is not appearing on the 12m HM). The strong arrival about 3sec later on the vertical geophone on the OBS is a classic DSFA. It is a larger arrival here on the co-located hydrophone module than the similar arrival in Example #2 (Figure 28b).

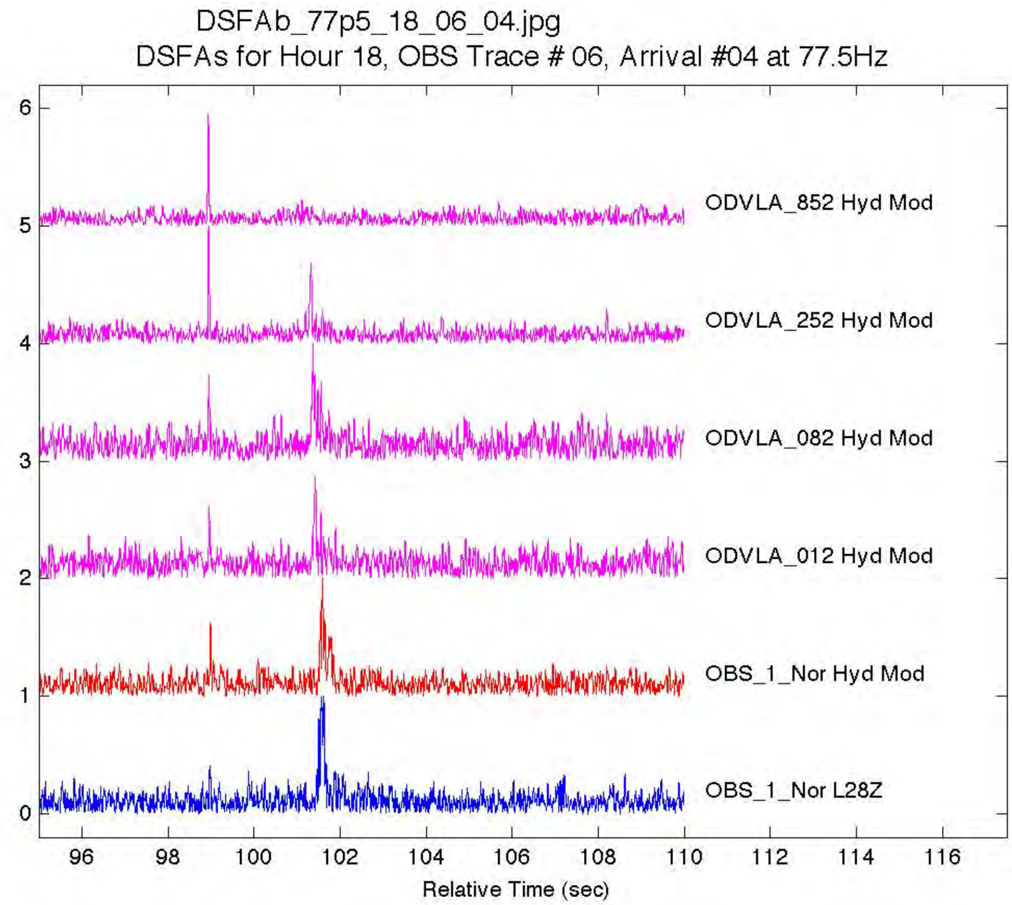


Figure 29c DSFA Example #4
This is the same format as above for the fourth transmission (of five) on the 132JD0625trace in Figure 29a. The range to the North OBS (bottom two traces) was 29.8km and the range to the O-DVLA (top four traces) was 31.2km. In this example the PE predicted arrival decays with increasing depth and is smaller than the second (DSFA) arrival on the lower O-DVLA modules and on the seafloor. Strangely the PE predicted arrival is almost undetectable on the vertical geophone but is quite strong on the co-located hydrophone. If one only had the vertical geophone (on the seafloor) and the O-DVLA module at 852m, one would assume that the single arrivals on these two sensors were the same arrival and that there must be a clock error (of about 3sec) somewhere.

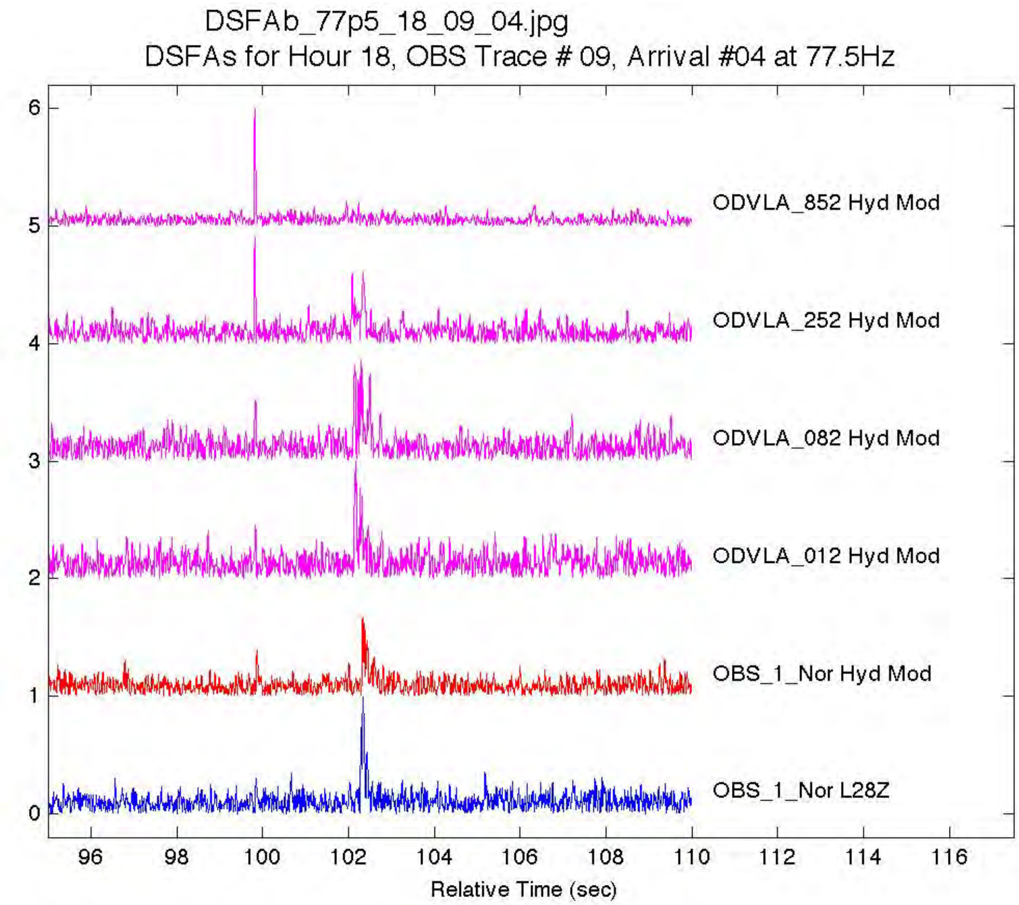


Figure 29d DSFA Example #5

This is the same format as above for the fourth transmission (of five) on the 132JD0640trace in Figure 29a. The range to the North OBS (bottom two traces) was 31.1km and the range to the O-DVLA (top four traces) was 32.5km. In this example the PE predicted arrival decays even more dramatically with increasing depth than in Example #4 and it is undetectable on the vertical geophone. If one only had the vertical geophone (on the seafloor) and the O-DVLA module at 852m, one would assume that the single arrivals on these two sensors were the same arrival and that there must be a clock error (of about 3sec) somewhere.

iii) About 10km to the Northeast on the South OBS

This set of examples for short range propagation to the South OBS shows bathymetric blockage of the PE predicted arrival (the South OBS is in the shadow zone of a hill) but a DSFA simultaneously builds and remains strong. It is an example of strong DSFAs persisting in the shadow zone for PE predicted arrivals. The South OBS is on the southwest facing slope of a small seamount (Figure 8). The summit of the small seamount is about 365m above the base of the O-DVLA, the South OBS is about 146m below the summit, and the South OBS is 219m above the base of the DVLA (Figure 10b and Table 6).

Figures 30a and 30b show the time-compressed traces for hours 1 and 2 on JD132 on the northeast line for the vertical component geophone on the South OBS. Ranges, to the northeast, varied from 4.9km (at the bottom) to 9.3km (at the top) for hour 1 and 9.7km to 14.3km for hour 2. In Figure 30a it is interesting how the arrivals change from a single peak on the short range traces to doublets on the long range traces, with the single peak aligned with the first peak of the doublet. Then in Figure 30b, the arrivals change from doublets on the short range traces to single peaks on the long range traces, with the single peak aligned with the second peak of the doublet. We chose to look at five events in more detail:
Example # 6 - transmission number 3 (at about 55sec) on the 20minute trace in hour 1 (Figure 30a), Example #7 - transmission number 3 (at about 55sec) on the 0.0minute trace in hour 2 (Figure 30b), Example #8 - transmission number 3 (at about 55sec) on the 5minute trace, in hour 2 (Figure 30b), Example #9 - transmission number 3 (at about 55sec) on the 10minute trace in hour 2 (Figure 30b), and Example #10 - transmission number 3 (at about 55sec) on the 35minute trace in hour 2 (Figure 30b), in Figures 30c through 30g respectively.

In this sequence of examples the O-DVLA arrivals change very little - there is just a single strong direct path arrival - but the OBS geophone and hydrophone arrivals change dramatically. At short ranges (less than 6.5 for the OBS) we get single peaks corresponding to the direct path from the source (Example #6, Figure 30c). At somewhat longer ranges (9.7km), in addition to the direct path we get a DSFA arrival occurring about 6.5sec later on the vertical geophone but not on the co-located hydrophone module (Example #7, Figure 30d). Just 0.4km further (10.1km Example #8, Figure 30e) the OBS hydrophone module trace changes completely. We lose the direct path arrival and gain a family of DSFA arrivals about 5.5 sec later that do not coincide with the vertical geophone trace. The vertical geophone trace changes only slightly. Then 0.5km further (10.6km, Example #9, Figure 30f) the DSFA arrival on the vertical geophone becomes larger than the direct arrival and there is a weak correspondence with an event in the arrival packet on the co-located hydrophone. By a range of 12.6km the OBS geophone and hydrophone traces correlate very well but there is no sign of a direct wave on either trace.

We cannot explain why the vertical geophone and co-located hydrophone traces do not track one another more closely. The O-DVLA traces are solid, as one would expect, at these short ranges where the direct path insonifies the deep receivers and there is no bathymetric blockage. We attribute the DSFA behavior on the South OBS to bathymetric blockage from the seamount described above. When the seamount is not in the way everything looks fine. When one gets to ranges where grazing rays from the source are blocked by the seamount, we lose the direct path

arrival. In the intermediate ranges where we are losing the direct path, we seem to gain the DSFA arrival, about 6.5sec later. Eventually at far enough ranges we do not get the direct path at all and only the DSFA arrival is observed.

Could the DSFA arrival be the first water-multiple - ie a bottom-reflected surface-reflected (BRSR) phase - that bounces over the seamount? Yes, possibly. We have not done PE modeling yet but the delay between DSFA and direct arrival is about right. Since we do not have the O-DVLA directly above the seamount we cannot see the decay of the DSFA with height above the seafloor that we saw in Examples #1 - #5. Given how strong this arrival appears at the seafloor OBS, if it were a BRSR phase one would expect to see it on the O-DVLA (without the seamount in the way).

Nonetheless this is an example at short range (less than 13km) where energy transitions from one path to another. The SNRs in Section 10a and Figures 26 and 27 for the South OBS are not tracking a single phase.

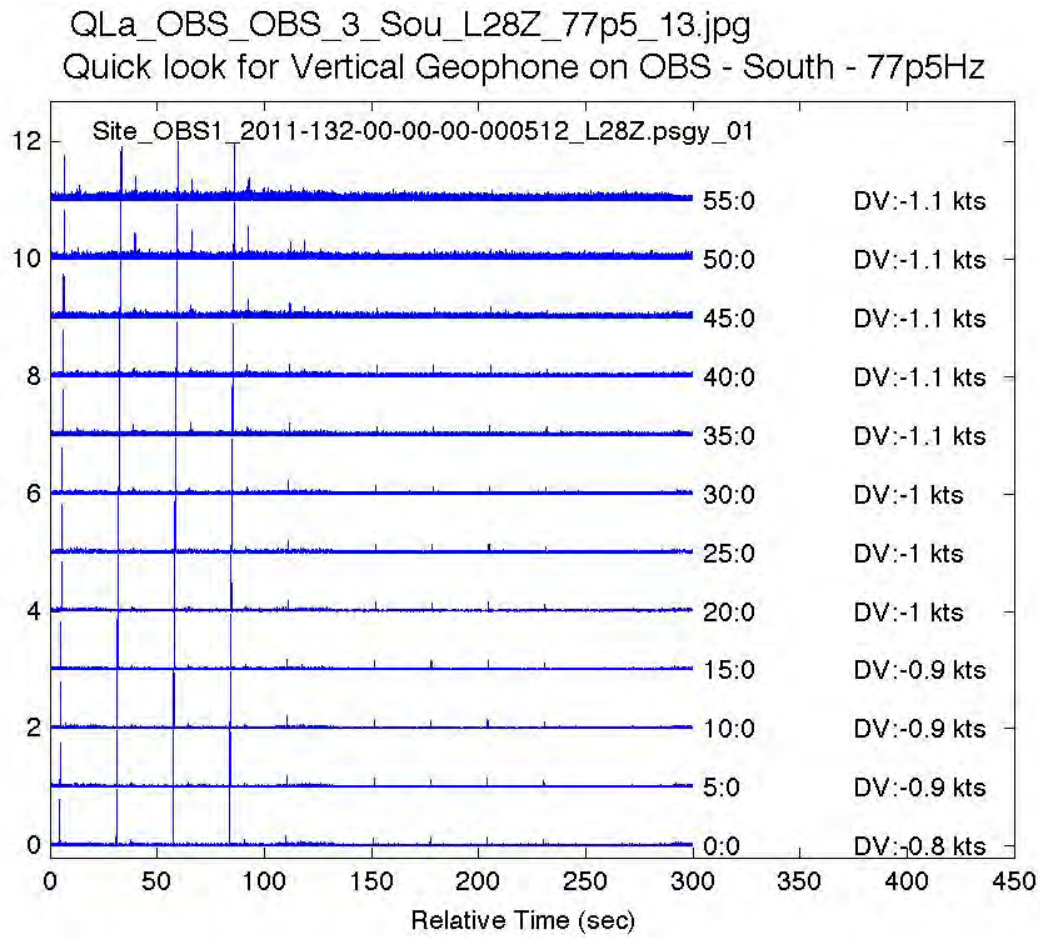


Figure 30a 77.5Hz Time-Compressions on the Vertical Geophone - South OBS - JD132 0100Z

The time-compressed traces at 77.5Hz for hour 1 on JD132 on the northeast line for the vertical component geophone on the South OBS. Ranges varied from 4.9km (at the bottom) to 9.3 km (at the top). Although we transmitted only four M-sequences, because of overlapping windows we get five apparent transmissions - near 5, 30, 55, 80 and 105sec on this plot. The bottom, short range, traces show single peak arrivals. The top, longer range, traces show doublets with the first peak of the doublet larger than the second. The single peak aligns with the first peak of the doublet. We chose to look at one event here in more detail: Example # 6 - transmission number 3 (at about 55sec) on the 20minute trace.

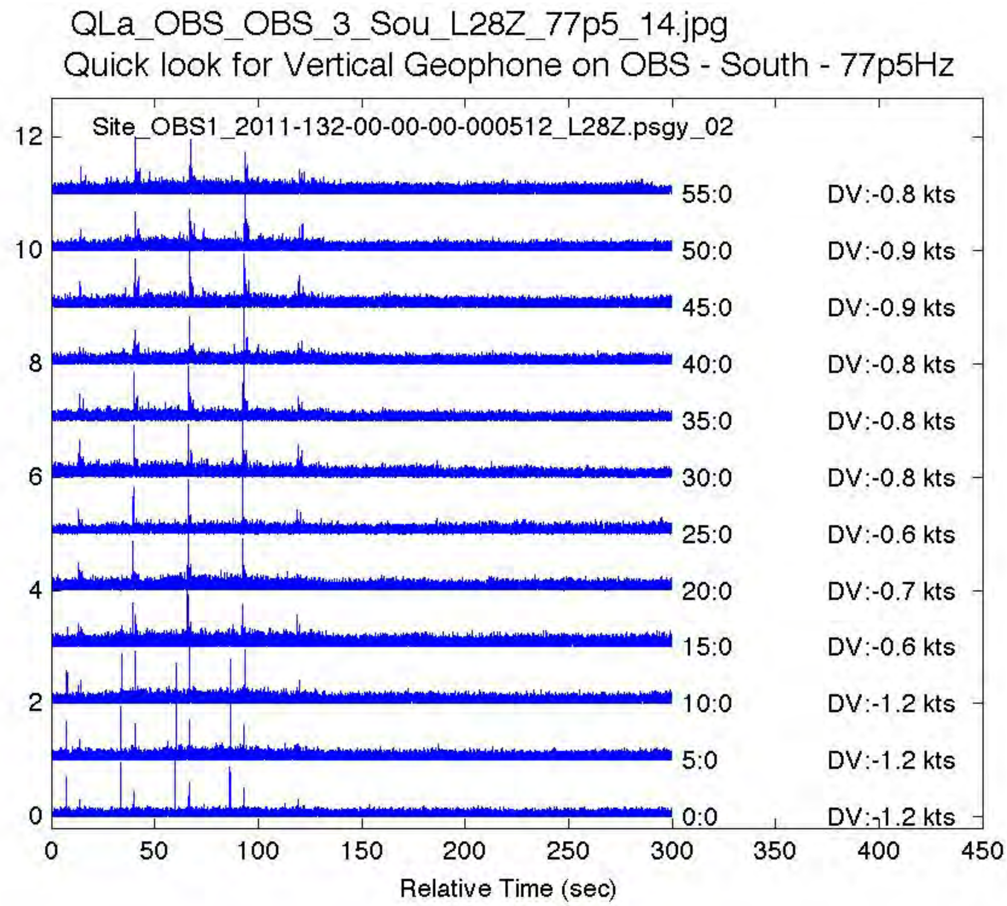


Figure 30b 77.5Hz Time-Compressions on the Vertical Geophone - South OBS - JD132 0200Z

The time-compressed traces at 77.5Hz for hour 2 on JD132 on the northeast line for the vertical component geophone on the South OBS. Ranges varied from 9.7km (at the bottom) to 14.3 km (at the top). Although we transmitted only four M-sequences, because of overlapping windows we get five apparent transmissions - near 5, 30, 55, 80 and 105sec on this plot. The bottom, short range, traces show doublet arrivals. The top, longer range, traces show single peaks which align with the second peak of the doublet. We chose to look at four events here in more detail: Example #7 - transmission number 3 (at about 55sec) on the 0.0minute trace, Example #8 - transmission number 3 (at about 55sec) on the 5minute trace, Example #9 - transmission number 3 (at about 55sec) on the 10minute trace and Example #10 - transmission number 3 (at about 55sec) on the 35minute trace.

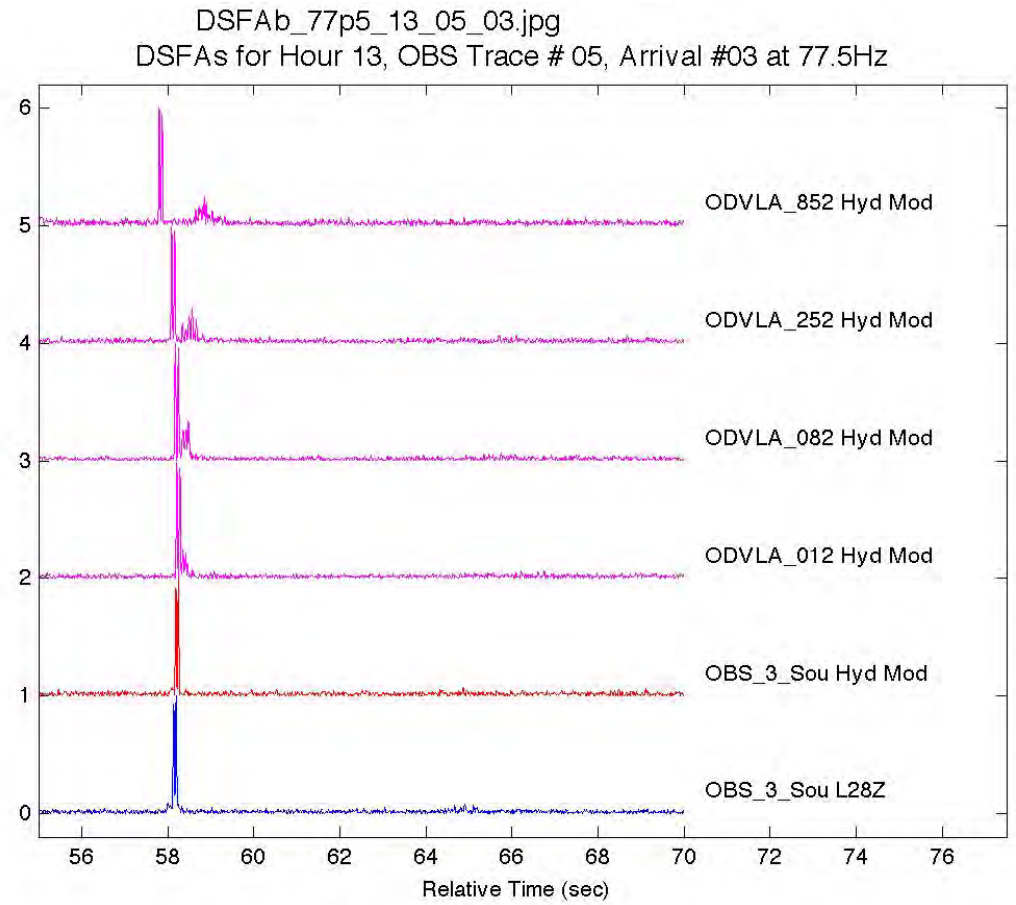


Figure 30c DSFA Example #6

This is the same format as Figure 28b (and others above) for the third transmission (of five) on the 132JD0120 trace in Figure 30a. The range to the South OBS (bottom two traces) was 6.5km and the range to the O-DVLA (top four traces) was 4.7km. We see a single large peak near 58sec, the "PE predicted" arrival, which is the direct wave from the source. On the O-DVLA traces at 82m and above the arrival is split into incident and seafloor reflected arrivals.

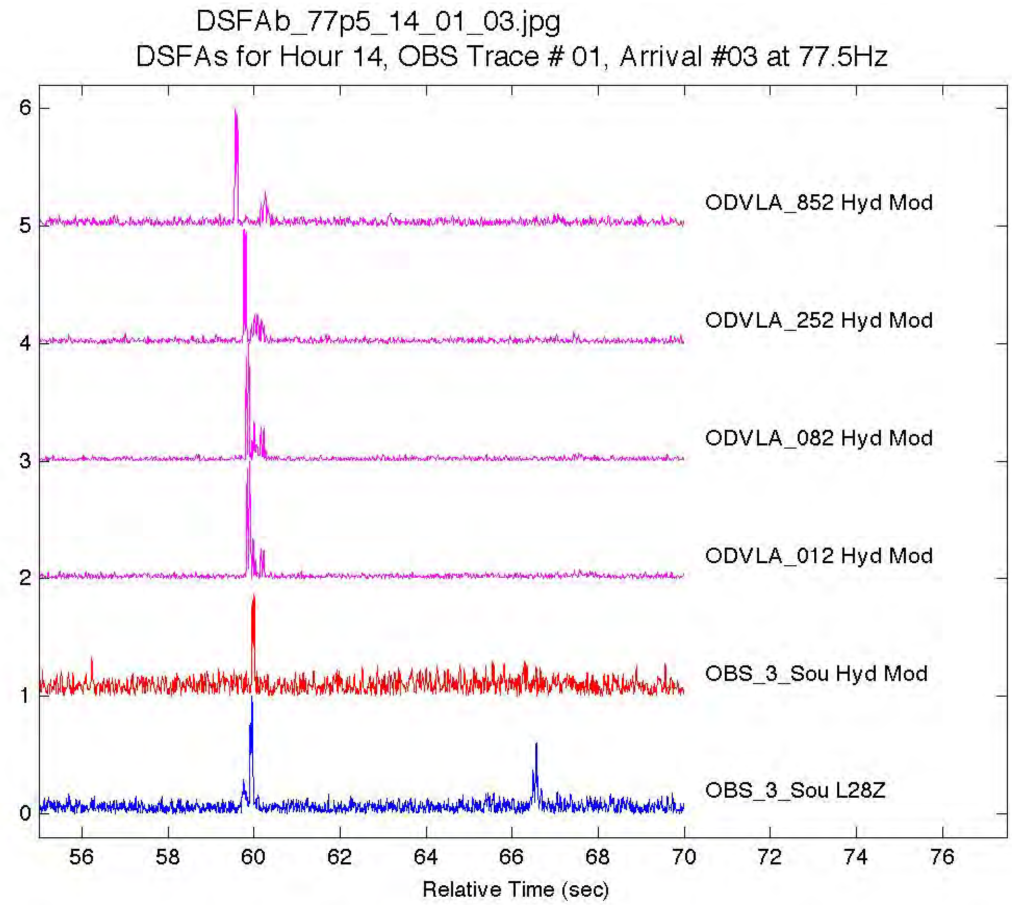


Figure 30d DSFA Example #7
This is the same format as above for the third transmission (of five) on the 132JD0200 trace in Figure 30b. The range to the South OBS (bottom two traces) was 9.7km and the range to the O-DVLA (top four traces) was 8.1km. We see a single large peak near 60sec, the "PE predicted" arrival, similar to Example #6, which is the direct wave from the source. There is also a DSFA arrival about 6.5sec later on the vertical component geophone, but there is no indication of this event on the co-located hydrophone module.

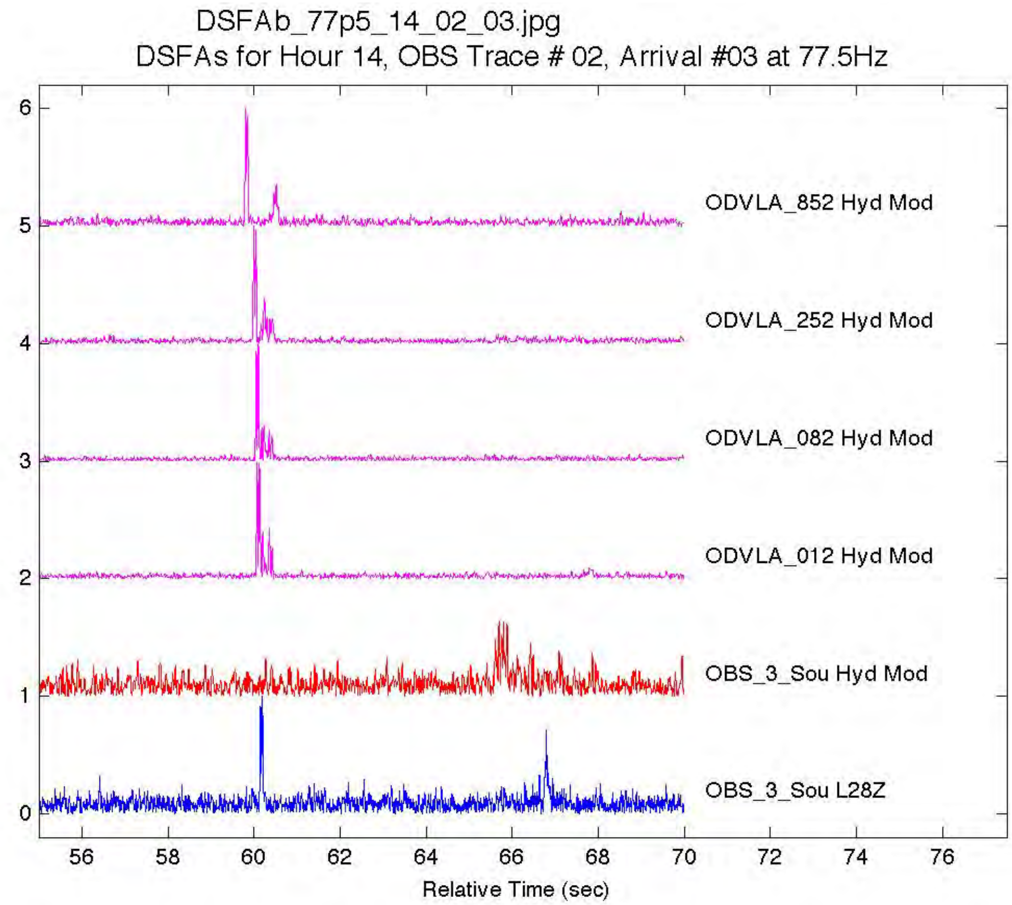


Figure 30e DSFA Example #8

Now things get really strange. This is the same format as above for the third transmission (of five) on the 132JD0205 trace in Figure 30b. The range to the South OBS (bottom two traces) was 10.1km and the range to the O-DVLA (top four traces) was 8.5km. We see the single large peak near 60sec, the "PE predicted" arrival, similar to Example #6 and #7, on all receivers except the hydrophone module on the South OBS. What could have happened to wipe-out this event? Then we see a family of four events occurring between 65.5 and 68sec, but not coinciding with the DSFA arrival on the vertical geophone. It is remarkable how much the OBS hydrophone module changed from Example #7 which was only 0.4km away.

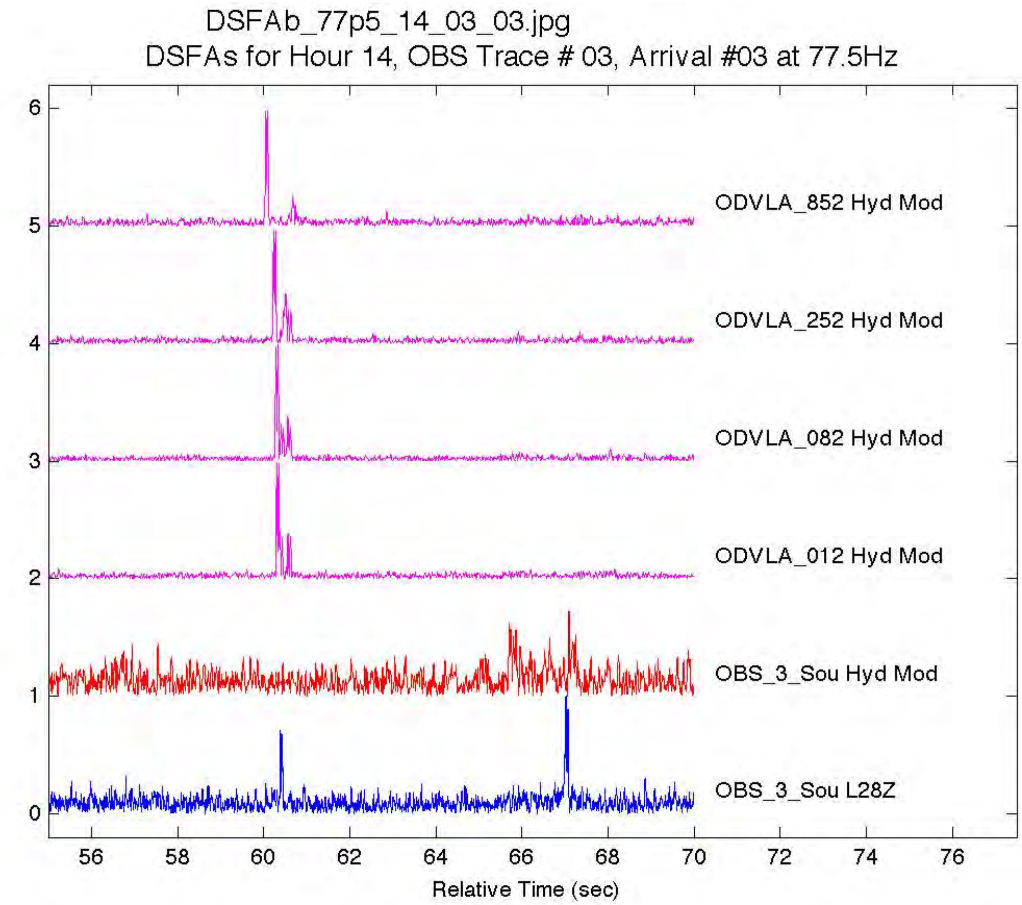


Figure 30f DSFA Example #9
This is the same format as above for the third transmission (of five) on the 132JD0210 trace in Figure 30b. The range to the South OBS (bottom two traces) was 10.6km and the range to the O-DVLA (top four traces) was 8.9km. As in Example #8 we see the single large peak near 60sec, the "PE predicted" arrival on all receivers except the hydrophone module on the South OBS. We see the diffuse family of events occurring between 65.5 and 68sec, with one arrival that does seem to coincide with the DSFA arrival on the vertical geophone.

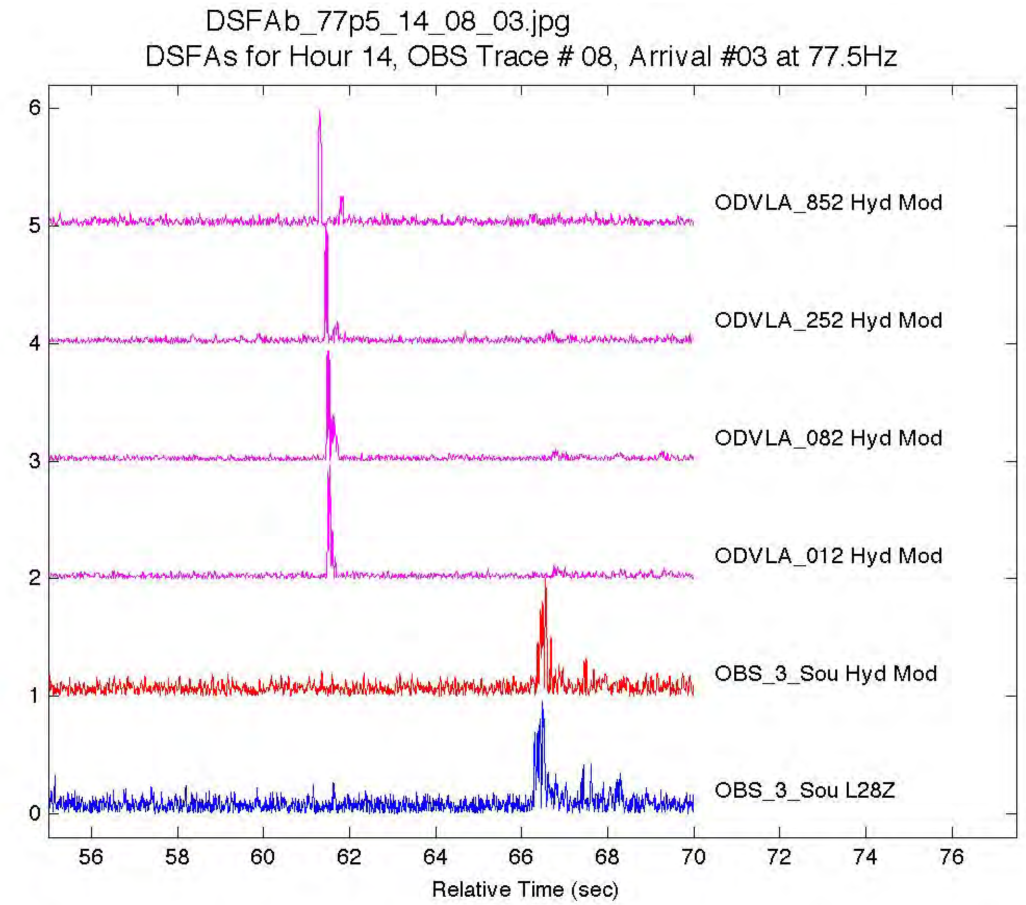


Figure 30g DSFA Example #10

This is the same format as above for the third transmission (of five) on the 132JD0235 trace in Figure 30b. The range to the South OBS (bottom two traces) was 12.6km and the range to the O-DVLA (top four traces) was 11.0km. The "PE predicted" arrival, near 61sec, is no longer present on either of the OBS receivers. The DFSA arrival has the same appearance on both of the OBS receivers , as one would expect.

10c. Spectral Analysis

We computed a few spectra on selected receivers i) to get a rough idea of the performance, ii) to do a sanity check on instrument transfer functions and sensitivities, and iii) to compare ambient noise levels with previous experiments such as NPAL04, Church OPAL, H2O, etc. Ultimately we would like to do spectrograms for the whole duration of the experiment, compute some statistics on the ambient noise, correlate ambient noise with environmental parameters such as sea state and local wind speed, and compare these results with previous experiments.

Sample spectra are computed for the first ten minutes or so of the JD131 1300Z. We plot spectra up to 3/4 of the Nyquist frequency.

i) Acoustic Pressure Spectra

Figure 31 compares spectra for five hydrophone modules: the shallowest HM on the O-DVLA (852m above the seafloor), the deepest HM on the O-DVLA (12m above the seafloor), and the HMs on the three OBSs. The passband of the HMs, over which the frequency response is flat, is from 10Hz to the Nyquist. We have tried to compensate for the roll-off of the transfer function below 10Hz but this work is still in progress.

All five sensors have roughly the same spectral level. Between 10 and 100Hz, the shallowest HM on the O-DVLA is a few dB noisier than the HMs near the seafloor. From 2 to 8Hz the HM on the South OBS is slightly noisier than the others.

Figure 32 compares spectra for the three acoustic pressure sensors deployed on OBSAPS: OBSIP hydrophones on the three short period OBSs, DPGs on the two long period BBOBS, and the HMs (in Figure 31). All sensors are within a 2.2km radius of the O-DVLA. The passband for the OBSIP hydrophones is 0.05Hz to 7.5KHz and for the OBSIP DPGs is 0.010Hz to 10Hz. The HMs are on the same OBSs as the OBSIP hydrophones, so these results should be identical. We still need to work on the transfer function below 10Hz for the HMs. It is encouraging that the micro-seism peak, 0.2-0.4Hz, is resolved on all sensors.

We had thought that the poor performance of the time compressions on the OBSIP hydrophones compared to the HMs (Section 10a) was due to high system noise levels, but there is no indication of that here. At high frequencies system noise would be indicated by a straight spectrum, either flat or rising with frequency, but there is only a slight indication of system noise issues for the OBSIP OBS above 150Hz or so. Of course the rise in spectral levels for all sensors below 0.1Hz is low frequency system noise. It is interesting that the low frequency performance of the DPGs is no better than the OBSIP hydrophones. DPGs are specifically designed for very low frequency and should resolve the deep noise notch around 0.03Hz. This notch is resolved on the long period inertial sensors as shown in the next section. There is an offset of a few dB in the DPG levels with respect to the OBSIP hydrophones which may indicate a calibration issue.

Figure 33 compares spectra for the three OBSAPS acoustic sensors with the two sensors from NPAL04: OBSIP hydrophone and DVLA hydrophone. The lowest black line is the spectrum for the OBS hydrophone with shorted inputs and is a proxy for system noise. The straightness of the "good" OBS hydrophone spectra (upper three black lines) between 5 and 100Hz and the similarity of the slope with the shorted OBS suggests that the NPAL OBS hydrophones were system noise limited from 5 to 100Hz. In fact very little useful analysis was done with the OBS hydrophones on NPAL04.

The similarity of the NPAL04 DVLA spectra with the OBSAPS spectra from 5 to 500Hz is encouraging. Note that the NPAL04 DVLA hydrophones did not resolve the micro-seism peak but all three OBSAPS sensors did. The NPAL04 OBS hydrophones, that were system noise limited at high frequencies, actually resolve the micro-seism peak the best of all sensors - note the steep slope of these spectra just above 0.1Hz.

Figure 34 compares the OBSAPS spectra with historical spectra. The H20 spectra show clearly the noise notch between 0.03 and 0.2Hz. These were acquired with a DPG and it is not clear why the OBSAPS DPG did not resolve this noise notch better. Above 10 Hz the H2O spectra rise quickly, possibly due to system noise. There is no indication of this rise on any of the OBSAPS acoustic sensors. These OBSAPS samples are comparable to H2O on a noisy day in the 5 to 10Hz band. There is no indication yet that OBSAPS levels will approach the levels of H2O on a quiet day (5-10Hz) or the quiet levels on Church OPAL (10-100Hz). Ideally a good acoustic sensor for OBSAPS and NPAL04 style experiments would have system noise below 40dB for the 5 to 1000Hz band.

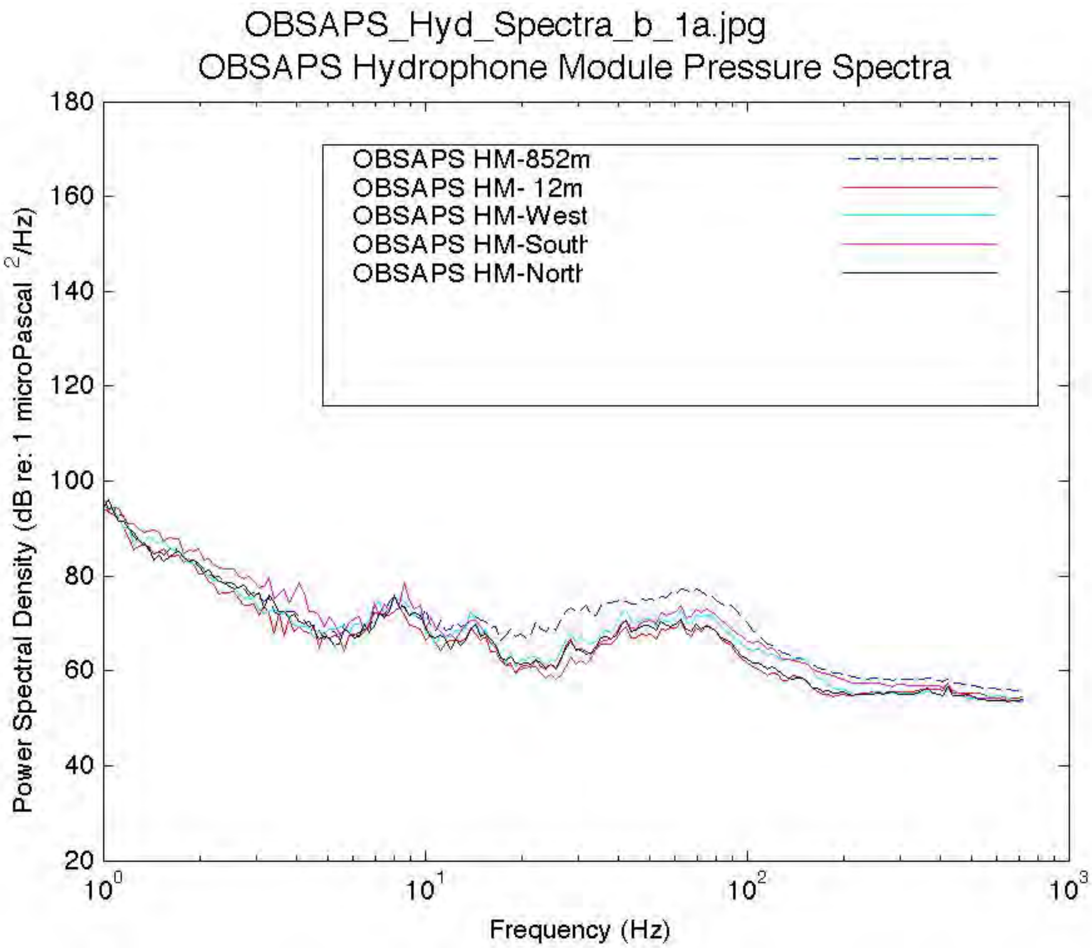


Figure 31 Samples of Spectra for Five Hydrophone Modules
Comparison of spectra for five hydrophone modules: the shallowest HM on the O-DVLA (852m above the seafloor), the deepest HM on the O-DVLA (12m above the seafloor), and the HMs on the three OBSs.

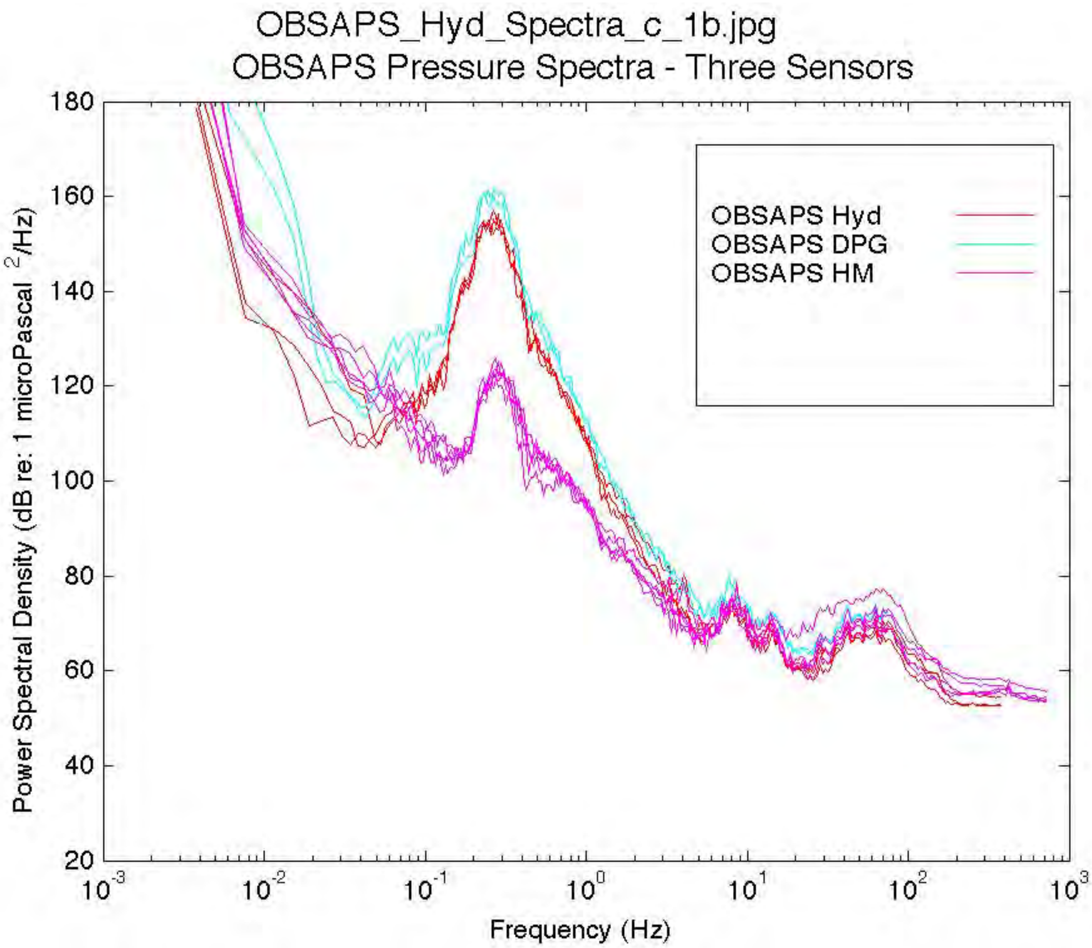


Figure 32 Comparison of Spectra for the Three Acoustic Pressure Sensors
Comparison of spectra for the three acoustic pressure sensors deployed on OBSAPS: OBSIP hydrophones on the three short period OBSs (red), DPGs on the two long period BBOBS (cyan), and the HMs (magenta, in Figure 31).

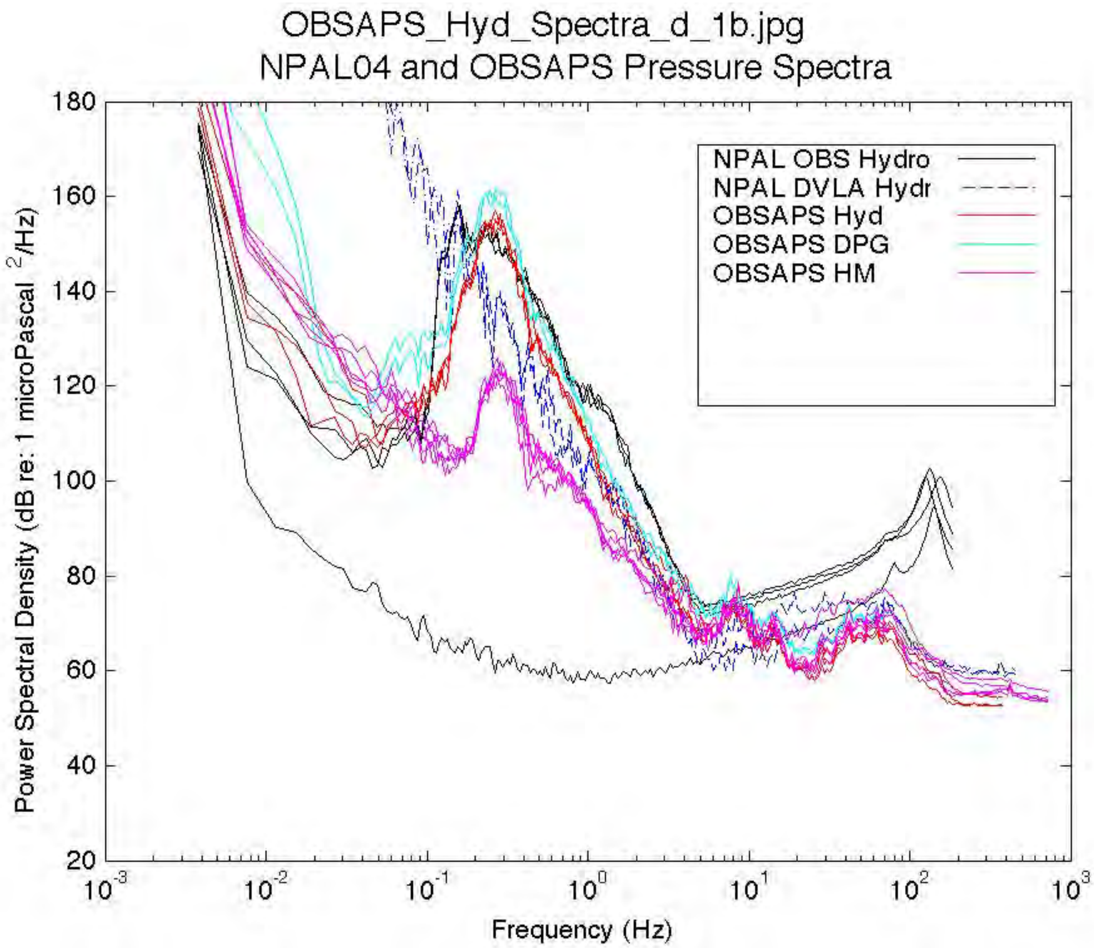


Figure 33 Comparison of OBSAPS Pressure Spectra with NPAL04
Comparison of spectra for the three OBSAPS acoustic sensors with the two sensors from NPAL04: OBSIP hydrophone and DVLA hydrophone.

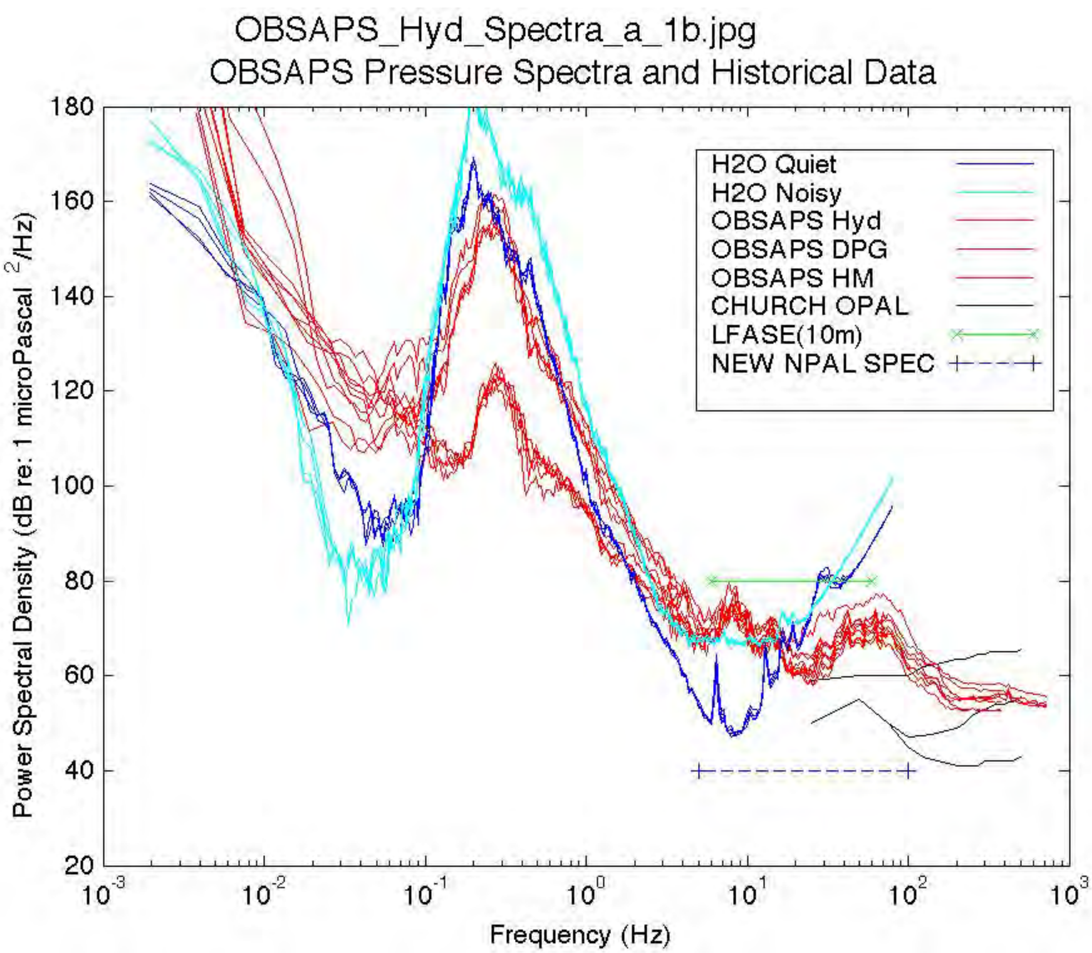


Figure 34 Comparison of OBSAPS Pressure Spectra with Historical Spectra
Comparison of the OBSAPS spectra with historical spectra: LFASE, H2O, and Church OPAL.

ii) Inertial Sensor Spectra

Figure 35 shows samples of vertical particle velocity spectra for the three short-period and two long-period OBSs on OBSAPS. The passbands of the sensors are 4.5Hz to Nyquist and 240sec (0.004167Hz) to 35Hz respectively. The low frequency noise notch between 0.02 and 0.2sec is quite clear for the long-period sensors. The spectra should coincide at the micro-seism peak so more work needs to be done on transfer functions. The dashed lines are lower and upper bounds of ambient noise spectra based on compilations of land seismic data.

Figures 36a and 36b show the horizontal component spectra overlain on the vertical component spectra for the short period and long period OBSs respectively. Horizontal levels are at or slightly above vertical levels which is not uncommon. It is difficult to get good low-frequency long-period horizontal data because of seafloor tilts.

In Figure 37 the OBSAPS short and long period vertical component spectra (red) are compared to historical data sets: NPAL04, OSNPE (seafloor, buried and borehole) and H2O geophone. The long period OBSAPS sensors based on the Trillium 240 have comparable spectra at low frequencies to the OSNPE Guralps and KS54000. The short period OBSAPS sensors, 4.5Hz geophones, have comparable spectra to the LFASE (100m), NPAL04 and H20-Geophone spectra. So far we have not seen any spectra as quiet as H2O in the 5-40Hz band. OBSAPS spectra are about 20dB noisier than NPAL04 in the 5 to 20Hz band and are comparable to NPAL04 in the 20 to 150Hz band.

Some action items:

1) We need to resolve the discrepancy between the short period and long period transfer functions at micro-seism frequencies.

2) We need to resolve the discrepancy between the transfer functions for the SIO hydrophone modules and the OBSIP hydrophones at micro-seism frequencies.

3) Once the transfer functions are sorted-out we need to look at long time series in each experiment to determine extrema and statistics.

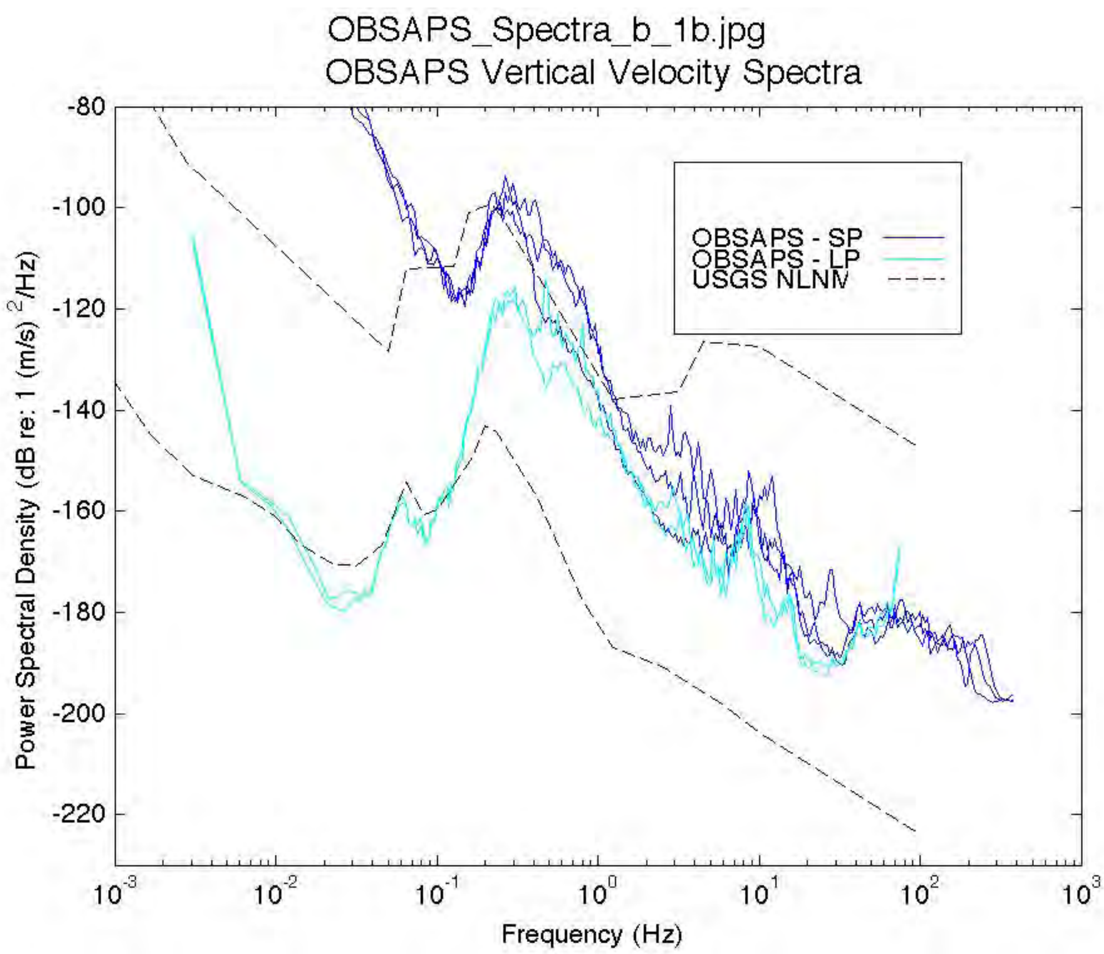


Figure 35 Samples of Spectra for Vertical Components on OBSs
Samples of vertical particle velocity spectra for the three short-period and two long-period OBSs on OBSAPS. The discrepancy at the microseism peak needs to be fixed.

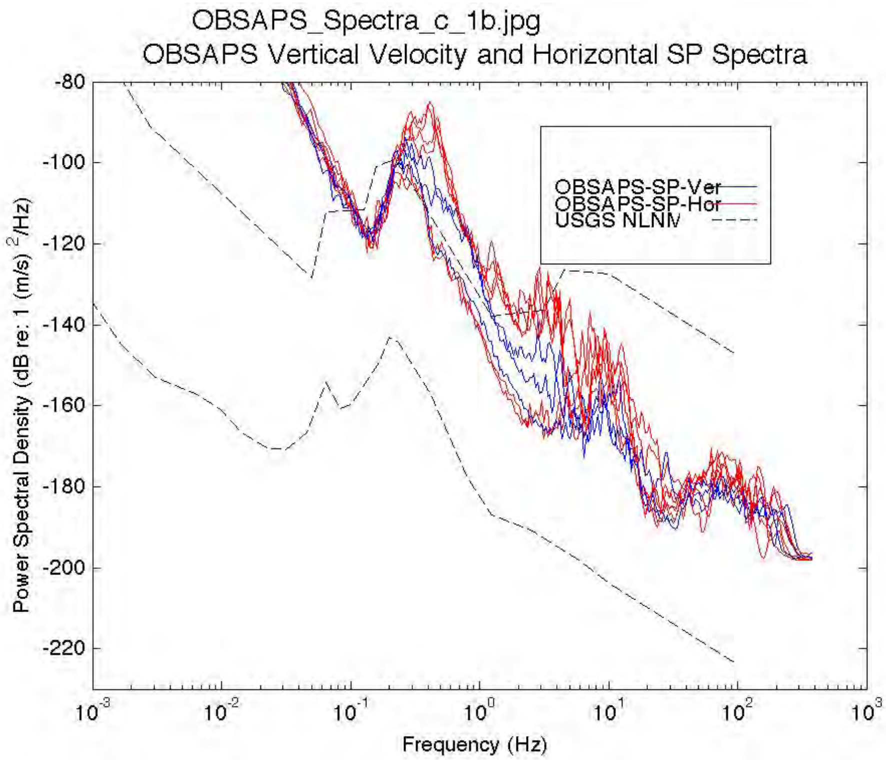


Figure 36a Comparison of Short Period Spectra on Verticals and Horizontals
Horizontal component spectra overlain on the vertical component spectra for the short period OBSs.

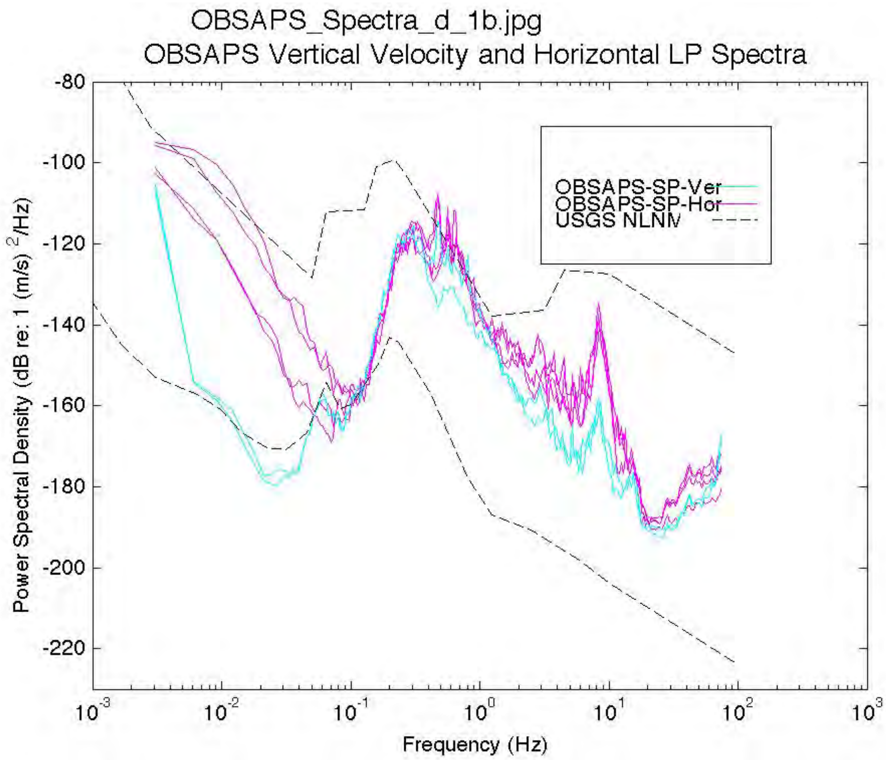


Figure 36b Comparison of Long Period Spectra on Verticals and Horizontals
Horizontal component spectra overlain on the vertical component spectra for the long period OBSs.

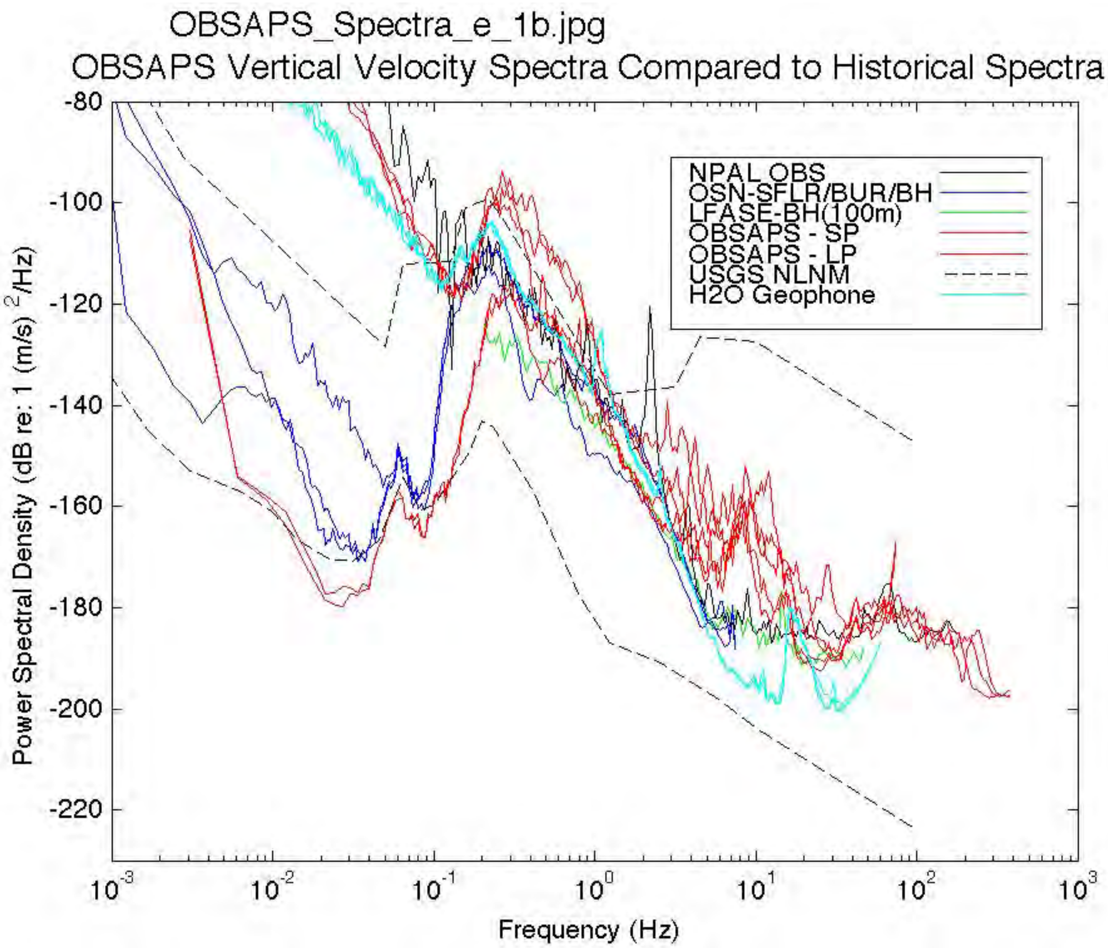


Figure 37 Comparison of OBSAPS Vertical Spectra with Historical Spectra
The OBSAPS short and long period vertical component spectra (red) are compared to historical data sets: NPAL04, OSNPE (seafloor, buried and borehole) and H2O geophone

11. Acknowledgements

We would like to thank Captain Desjardins, the officers and crew of the R/V Roger Revelle for an excellent cruise. Their competence and professional attitude during RR1106 were exemplary. We would also like to thank Gerald D'Spain, Keith von der Heydt, and Neil McPhee for assistance in preparing equipment for the cruise and for loaning us gear. Kevin Heaney provided valuable advice and software. This work was carried out under ONR Awards #N00014-10-1-0987 and N00014-10-1-0994. Additional post-cruise analysis support was provided to RAS through the Edward W. and Betty J. Scripps Chair for Excellence in Oceanography. The OBSs used in the experiment were provided by Scripps Institution of Oceanography under the U.S. National Ocean Bottom Seismic Instrumentation Pool SIO-OBSIP — http://www.obsip.org.

Appendix 1: OBSAPS Summary of Transmission Data Files

Julian Day	***Calendar Day***	***Station Name***	***Time Interval***	***Folder name***	***Test***	***Program***	***Speed***	***J15-3***	***DAC Gain***	***Wire-out depth (m)***
JD110	Wednesday, April 20	Kaohsiung			Kaohsiung J15-3 Harbor Tests - Primary 4, Gains 1 to 2					
			0128 to 0148	OBSAPS_Primary_Sea_04_3_4K_DAC_gain1	DAC Gain 1	Primary 4	N/A	#11 - as delivered	1	1
			0221	OBSAPS_Primary_Sea_04_3_4K_DAC_gain2	DAC Gain 2.0	Primary 4	N/A	#11 - as delivered	2	1
			0230 to 0240	OBSAPS_Primary_Sea_04_3_4K_DAC_gain1.5	DAC Gain 1.5	Primary 4	N/A	#11 - as delivered	1.5	1
			0246 to 0255	OBSAPS_Primary_Sea_04_3_4K_DAC_gain1.25	DAC GAin 1.25	Primary 4	N/A	#11 - as delivered	1.25	1
			0300 to 0309	OBSAPS_Primary_Sea_04_3_4K_DAC_gain1.75	DAc Gain 1.75	Primary 4	N/A	#11 - as delivered	1.75	1

Julian Day	Calendar Day	Station Name	Time Interval	Folder name	Test	Program	Speed	J15-3	DAC Gain	Wire-out depth (m)
JD111	Thursday, April 21	Kaohsiung			Kaohsiung Harbor Tests on a Space Heater with a signal generator, 250Hz CW					
			0911 to 0914	Vref_200mVp-p_250Hz	200mVp-p	Heater Tests	N/A	#11 - as delivered	N/A	N/A
			0917 to 0919	Vref_400mVp-p_250Hz	400mVp-p	Heater Tests	N/A	#11 - as delivered	N/A	N/A
			0921 to 0923	Vref_600mVp-p_250Hz	600mVp-p	Heater Tests	N/A	#11 - as delivered	N/A	N/A
			0925 to 0926	Vref_800mVp-p_250Hz	800mVp-p	Heater Tests	N/A	#11 - as delivered	N/A	N/A
			0928 to 0929	Vref_1000mVp-p_250Hz	1000mVp-p	Heater Tests	N/A	#11 - as delivered	N/A	N/A
			0931 to 0932	Vref_1200mVp-p_250Hz	1200mVp-p	Heater Tests	N/A	#11 - as delivered	N/A	N/A
			0936 to 0937	Vref_1200mVp-p_400Hz	1200mVp-p@400Hz	Heater Tests	N/A	#11 - as delivered	N/A	N/A
JD112	Friday, April 22	Kaohsiung			Kaohsiung J15-3 Harbor Tests, CW, LFM, & Primary 4					
			0717 to 0724	CW310_no_HP_H-	no Hi-pass filter - DAC	CW Tests	N/A	#11 - as delivered	1	1

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
				91_DACgain1	GAin = 1					
			0732 to 0735	CW310_with_HP_H-91_DACgain1	Hi-pass filter - DAC Gain = 1	CW Tests	N/A	#11 - as delivered	1	1
			0740 to 0750	CW310_with_HP_H-91_DACgain1.22	Hi-pass filter - DAC Gain = 1.22	CW Tests	N/A	#11 - as delivered	1.22	1
			0755 to 0804	OBSAP_Primary_Sea_04_3_4K_DACgain1	After filters added, Primary 4, DAC Gain = 1	Primary 4	N/A	#11 - as delivered	1	1
			0808 to 0816	OBSAPS_Primary_Sea_04_3_4K_DACgain1.25	DAC Gain = 1.25	Primary 4	N/A	#11 - as delivered	1.25	1
			0820 to 0830	OBSAPS_Primary_Sea_04_3_4K_DACgain1.50	DAC Gain = 1.50	Primary 4	N/A	#11 - as delivered	1.5	1
			0833 to 0842	OBSAPS_Primary_Sea_04_3_4K_DACgain1.75	DAC Gain = 1.75	Primary 4	N/A	#11 - as delivered	1.75	1
			0846 to 0849	lfm_updown_60s_4kHz_run1	LFM run 1	LFM Tests	N/A	#11 - as delivered	1.21	1
			0853 to 0855	lfm_updown_60s_4kHz_run2	LFM run 2	LFM Tests	N/A	#11 - as delivered	1.21	1

Julian Day	Calendar Day	Station Name	Time Interval	Folder name	Test	Program	Speed	J15-3	DAC Gain	Wire-out depth (m)
JD116	Tuesday, April 26	Kaohsiung			Kaohsiung J15-3 Harbor Tests					
			0201 to 0206	BNC_2090_jumperW1_test1	DAQ System Eng Test Grounding Mods - search for attenuation cause - no effect found		N/A			
			0237 to 0240	BNC_2090_jumperW1_test3	DAQ System Eng Test Grounding Mods - search for attenuation cause - no effect found		N/A			
			0247 to 0249	BNC_2090_jumperW1_test2	DAQ System Eng Test Grounding Mods - search for attenuation cause - no effect found		N/A			
			0259 to 0303	BNC_2090_jumperW1_test4	DAQ System Eng Test Grounding Mods - search for attenuation		N/A			

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
					cause - no effect found					
			0449 to 0458	OBSAPS_Primary_Sea_CW_1_4K_DACgain1	Primary 4 CW, DAc Gain = 1.0	Primary 4 CW	N/A	#11 - as delivered	1	1
			0504 to 0514	OBSAPS_Primary_Sea_CW_1_4K_DACgain1.75	Primary 4 CW, DAc Gain = 1.75	Primary 4 CW	N/A	#11 - as delivered	1.75	1
			0646 to 0651	OBSAPS_Primary_Sea_CW_1_4K_DACgain1.5	Primary 4 CW, DAc Gain = 1.5	Primary 4 CW	N/A	#11 - as delivered	1.5	1
			0659 to 0706	OBSAPS_Primary_Sea_CW_1_4K_DACgain0.75	Primary 4 CW, DAc Gain = 0.75	Primary 4 CW	N/A	#11 - as delivered	0.75	1
			0711 to 0720	OBSAPS_Primary_Sea_CW_1_4K_DACgain1.75b	Primary 4 CW, DAc Gain = 1.75, Run 2	Primary 4 CW	N/A	#11 - as delivered	1.75	1
			0725	OBSAPS_Primary_Sea_CW_1_4K_DACgain2	Primary 4 CW, DAc Gain = 2.0	Primary 4 CW	N/A	#11 - as delivered	2	1
			0732 to 0748	OBSAPS_Primary_Sea_CW_1_4K_DACgain2b	Primary 4 CW, DAc Gain = 2, Run 2	Primary 4 CW	N/A	#11 - as delivered	2	1

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
			0807 to 0816	OBSAPS_Primary_Sea_CW_1_4K_DACgain2.25	Primary 4 CW, DAc Gain = 2.25	Primary 4 CW	N/A	#11 - as delivered	2.25	1
			0819 to 0828	OBSAPS_Primary_Sea_CW_1_4K_DACgain2.5	Primary 4 CW, DAc Gain = 2.5	Primary 4 CW	N/A	#11 - as delivered	2.5	1
			0832 to 0842	OBSAPS_Primary_Sea_04_3_4K_DACgain2.5	Primary 4, DAC Gain =2.5	Primary 4	N/A	#11 - as delivered	2.5	1
JD117	Wednesday, April 27	Kaohsiung			Kaohsiung J15-3 Harbor Tests					
			0300 to 0310	lfm_updown_tenmin_4kHz_DACgain1.22_1meter	LFm for limnearity at 1.0m deoth	LFM test	N/A	#11 - as delivered	1.22	1
			0317 to 0322	fadeout_fivemin_775_4kHz_DACgain2.0	Fade-out test	Fade-out test	N/A	#11 - as delivered	2	1
			0328 to 0333	fadeout_fivemin_155_4kHz_DACgain2.0	Fade-out Test for amplitude dependence of linearity	Fade-out test	N/A	#11 - as delivered	2	1
			0415 to 0422	H-91_Spike_Experiments	Tests to see spikes in H91 traces	Spike test	N/A	#11 - as delivered	1.22	1

Julian Day	***Calendar Day***	***Station Name***	***Time Interval***	***Folder name***	***Test***	***Program***	***Speed***	***J15-3***	***DAC Gain***	***Wire-out depth (m)***
			0438 to 0730	OBSAPS_Primary_Sea_04_3_4K.sio_DACgain1.0	Three hour endurance test - Primary 4	Primary 4	N/A	#11 - as delivered	1	1
			0747 to 0757	lfm_updown_tenmin_4kHz_DACgain1.22_5meters	LFm for limnearity at 5.0m deoth	LFM test	N/A	#11 - as delivered	1.22	5
			0813 to 0828	OBSAPS_Primary_Sea_05_3_4K_DACgain1.0_5meters	Primary 5	Primary 5	N/A	#11 - as delivered	1	5
			0834 to 0924	Primary_Sea_06abc_3_4K_DACgain1.0_5meters	Primary 6	Primary 6abc	N/A	#11 - as delivered	1	5
JD121	Sunday, May 1	Q1								
		Q1	0226 to 0232	ambient_test_Depth_60m	Ambient Noise Test at Q1 at 80m	Ambient noise	Station Stop	#11 - as delivered	N/A	80
		Q1	0238 to 0244	OBSAPS_Primary_Sea_CW_1_4K_DACgain0.75_Depth_60m	CW for SPL tests at 60m DAC Gain = 0.75	Primary 4CW	Station Stop	#11 - as delivered	0.75	60
		Q1	0247 to 0252	OBSAPS_Primary_Sea_C	CW for SPL tests at 60m	Primary 4CW	Station Stop	#11 - as delivered	1.75	60

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
				W_1_4K_DACgain1.75_Depth_60m	DAC Gain = 1.75					
		Q1	0255 to 0300	OBSAPS_Primary_Sea_CW_1_4K_DACgain2.0_Depth_60m	CW for SPL tests at 60m DAC Gain = 2.0	Primary 4CW	Station Stop	#11 - as delivered	2	60
		Q1	0304 to 0308	OBSAPS_Priamry_Sea_CW_1_4K_DACgain2.25_Depth_60m	CW for SPL tests at 60m DAC Gain = 2.25	Primary 4 CW	Station Stop	#11 - as delivered	2.25	60
		Q1	0312 to 0317	OBSAPS_Primary_Sea_CW_1_4K_DACgain2.5_Depth_60m	CW for SPL tests at 60m DAC Gain = 2.5	Primary 4CW	Station Stop	#11 - as delivered	2.5	60
		Q1	0320 to 0329	ambient_test_with_sonobuoy_Depth_60m	Ambient noise test with sonobuoy at 60m depth	Ambient noise	Station Stop	#11 - as delivered	N/A	60
		Q1	0332 to 0337	lfm_up_fivemin_4kHz_40-960_DACgain1.22_Depth_60m	LFM test for linearity at 60m depth	LFM	Station Stop	#11 - as delivered	1.22	60
		Q1	0340 to 0355	fadeout_fivetones_fifteenmin_4kHz_DAC	Fade-out test for linearity at 60m depth	Fade-out	Station Stop	#11 - as delivered	2.5	60

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
				gain2.5_Depth_60m						
		Q1	0423 to 0433	OBSAPS_Primary_Sea_04_3_4K_DACgain2.5_Depth_60m	Primary 4 program at 60m depth DAC Gain = 2.5	Primary 4	Station Stop	#11 - as delivered	2.5	60
		Q1	0446 to 0452	ambient_test_80m	Ambient Noise Test at Q1 at 80m	Ambient noise	Station Stop	#11 - as delivered	N/A	80
		Q1	0500 to 0505	OBSAPS_Primary_Sea_CW_1_4K_DACgain2.0_Depth_80m	CW for SPL tests at 80m DAC Gain = 2.0	Primary 4CW	Station Stop	#11 - as delivered	2	80
		Q1	0509 to 0518	OBSAPS_Primary_Sea_CW_1_4K_DACgain_2.5_Depth_80m	CW for SPL tests at 80m DAC Gain = 2.5	Primary 4CW	Station Stop	#11 - as delivered	2.5	80
		Q1	0523 to 0529	lfm_up_fivemin_4kHz_40-960_DACgain_1.22_Depth_80m	LFM test for linearity at 80m depth	LFM	Station Stop	#11 - as delivered	1.22	80
		Q1	0538 to 0543	OBSAPS_Primary_Sea_04_3_4K_DACgain_2.5_Depth_80m	Primary 4 program at 80m depth DAC Gain = 2.5	Primary 4	Station Stop	#11 - as delivered	2.5	80

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
		Q1	0548 to 0553	ambient_test_with_sonobuoy_depth_100m	Ambient noise test with sonobuoy at 100m depth (*0548 to 0553)	Ambient noise	Station Stop	#11 - as delivered	N/A	100
		Q1	0615 to 1011	OBSAPS_Primary_6abc_DACgain2.5_Depth_60m	Primary 6 program for four hours at 60m depth, DAC Gain = 2.5 (*0853 to 0911)	Primary 6abc	Station Stop	#11 - as delivered	2.5	60
		Q2	1135 to 1531	OBSAPS_Primary_6abc_DACgain2.5_Depth_60m	Primary 6 program for four hours at 60m depth, DAC Gain = 2.5 (*1435 to 1447)	Primary 6	Station Stop	#11 - as delivered	2.5	60
		Q3	1653 to 2047	OBSAPS_Primary_6abc_DACgain2.5_Depth_60m	Primary 6 program for four hours at 60m depth, DAC Gain = 2.5 (*1935 to 1947)	Primary 6	Station Stop	#11 - as delivered	2.5	60
		TN	2239 to 2246	TN_ambient_test_depth_68-70m	Ambient noise test towing at 2.1kts, 70m	Ambient noise	2.1kts	#11 - as delivered	N/A	70

Julian Day	***Calendar Day***	***Station Name***	***Time Interval***	***Folder name***	***Test***	***Program***	***Speed***	***J15-3***	***DAC Gain***	***Wire-out depth (m)***
					wire out, depth was 68-70m					
		TN	2252 to 2253	TN_ambient_test_depth_60m	Ambient noise test towing at 2.1kts, 60m wire out	Ambient noise	2.1kts	#11 - as delivered	N/A	60
		TN to ~Q3	121/2305 to 122/0106	TN_tow_OBSAPS_Primary_Sea_04_3_4K_DACgain_2.5_Depth_60m	Primary 4 program towing at 2kts, DACgain = 2.5,tow depth 60m, 62m wire out - *** At 122/106 the J15-3 #11 open-circuited***	Primary 4	2.0kts	#11 - as delivered	2.5	62
JD122	Monday, May 2	Q3	0409 to 0414	TN_ambient_depth_60m_spare_J15-3	Testing J15-3 #14 at Q3, ambient noise at 60m depth	Ambient noise	Station Stop	#14 - as delivered	N/A	60
		Q3	0420 to 0426	TN_OBSAPS_Primary_Sea_CW_1_4K_DACgain_0.75_Depth_60m	CW for SPL tests at 60m DAC Gain = 0.75	Primary 4 CW	Station Stop	#14 - as delivered	0.75	60
		Q3	0431 to 0436	TN_OBSAPS_Primary_Sea_CW_1_4K_	CW for SPL tests at 60m DAC Gain =	Primary 4 CW	Station Stop	#14 - as delivered	1.75	60

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
				DACgain_1.75_Depth_60m	1.75					
		Q3	0442 to 0449	TN_OBSAPS_Primary_Sea_CW_1_4K_DACgain_2.50_Depth_60m	CW for SPL tests at 60m DAC Gain = 2.5 (*0442 to 0449)	Primary 4 CW	Station Stop	#14 - as delivered	2.5	60
		Q3	0457 to 0513	TN_OBSAPS_Primary_Sea_CW_1_4K_DACgain_2.0_Depth_60m	CW for SPL tests at 60m DAC Gain = 2.0	Primary 4 CW	Station Stop	#14 - as delivered	2	60
		Q3 to TS	122/0518 to 123/0512	OBSAPS_Primary_Sea_04_3_4K_DACgain2.0_Depth_60m	Primary 4 program towing at 2kts from Q3 to TS	Primary 4	2kts	#14 - as delivered	2	62
JD123	Tuesday, May 3	TSE	0842 to 0843	ambient_noise_test_depth_60m	Ambient noise test at 60m at TSE on J15-3 #14	Ambient Noise	Station Stop	#14 - as delivered	N/A	60
		TSE	0848 to 0858	OBSAPS_Primary_Sea_04_3_4K_DACgain_2.0_Depth_60m	Primary 4 program at TSE, 60m depth, DAC Gain = 2.0, "H91 Grounding issue"	Primary 4	Station Stop	#14 - as delivered	2	60

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
		TSE	0903 to 0905	OBSAPS_Primary_Sea_04_3_4K_DACgain2.0_Depth_60m_second_test	Primary 4 program at TSE, 60m depth, DAC Gain = 2.0, "H91 Grounding issue" - second test	Primary 4	Station Stop	#14 - as delivered	2	60
		TSE to TNW	123/0918 to 124/1224	OBSAPS_Primary_Sea_04_3_4K_DACgain_2.0_Depth_60m_TSE_to_TNW_tow	Primary 4 program towing at 2kts from TSE to TNW	Primary 4	2kts	#14 - as delivered	2	62
JD124	Wednesday, May 4	Q4			J15-3 #14 failed with multiple current overloads, replaced with the repaired J15-3 #11					
		Q4	1659 to 1703	OBSAPS_Primary_Sea_04_3_4K_DACgain_1.0_Depth_60m	Test Primary 4 program at 60m depth, DAc gain =1.0	Primary 4	Station Stop	#11- with replaced transducer	1	60
		Q4	1707 to	OBSAPS_Pri	Test Primary 4	Primary 4	Statio	#11- with	2	60

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
			1711	mary_Sea_04_3_4K_DACgain_2.0_Depth_60m	program at 60m depth, DAc gain =2.0		n Stop	replaced transducer		
		Q4	1715 to 2111	OBSAPS_Primary_6a_6b_6c_sequence_DACgain_2.0_Depth_2.0m	Primary 6 program for four hours at 60m depth, DAC Gain = 2.0 (*1915 to 1931)	Primary 6abc	Station Stop	#11- with replaced transducer	2	60
		Q5	124/2235 to 125/0031	Q5	Primary 6 program for two hours at 60m depth, DAC Gain = 2.0 (*2235 to 2247, 2315 to 2331, 2335 to 2347, 2353 to 0011)	Primary 6abc	Station Stop	#11- with replaced transducer	2	60
		Q6	125/0153 to 125/0347	Q6	Primary 6 program for two hours at 60m depth, DAC Gain = 2.0	Primary 6abc	Station Stop	#11- with replaced transducer	2	60
JD125	Thursday, May 5				Transiting from Q6 to R1					

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
					(Star of David) doing tow tests of speed, wire out and J15-3 depth.					
		Q6 to R1	0412 to 0417	ambient_noise_2.5knots_depth_70m_payedout80m	2.5knots, 80m wire out, 70m depth	Ambient Noise	Various	#11- with replaced transducer	N/A	80
		Q6 to R1	0420 to 0425	ambient_noise_3.0knots_depth_60m_payedout_80m	3.0knots, 80m wire out, 60m depth	Ambient Noise	Various	#11- with replaced transducer	N/A	80
		Q6 to R1	0427 to 0432	ambient_noise_3.5knots_depth_60m_payedout_80m	3.5knots, 80m wire out, 60m depth	Ambient Noise	Various	#11- with replaced transducer	N/A	60
		Q6 to R1	0434 to 0439	ambient_noise_4.0knots_51m_payedout_80m	4.0knots, 80m wire out, 51m depth	Ambient Noise	Various	#11- with replaced transducer	N/A	80
		Q6 to R1	0442 to 0448	ambient_noise_4.5knots_payedout_80m	4.5knots,80m wire out, 49m depth.	Ambient Noise	Various	#11- with replaced transducer	N/A	80
		Q6 to R1	0453 to 0458	ambient_noise_5.0knots_payedout_80m	5.0knots,80m wire out, 44m depth.	Ambient Noise	Various	#11- with replaced transducer	N/A	80
		Q6 to R1	0511 to 0521	ambient_noise_4.0knots_payedout_100m	4.0knots, 100m wire out, 62 m depth	Ambient Noise	Various	#11- with replaced transducer	N/A	100

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
		Q6 to R1	0525 to 0530	ambient_noise_4.5knots_payedout_100m	4.5knots,100m wire out, 57m depth.	Ambient Noise	Various	#11- with replaced transducer	N/A	100
		Q6 to R1	0535 to 0540	ambient_noise_5.0knots_payedout_100m	5.0knots,100m wire out, 52.5m depth.	Ambient Noise	Various	#11- with replaced transducer	N/A	100
		Q6 to R1	0544 to 0550	OBSAPS_Primary_04_3_4K_DACgain1_4.5knots_Depth57m	Test of Primary 4 sequence at 4.5knots,57m, DAC Gain = 1	Primary 4	4.5kts	#11- with replaced transducer	1	100
		Q6 to R1	0553 to 0558	OBSAPS_Primary_04_3_4K_DACgain1.5_4.5knots_Depth57m	Test of Primary 4 sequence at 4.5knots,57m, DAC Gain = 1.5	Primary 4	4.5kts	#11- with replaced transducer	1.5	100
		Star of David, R1-R12	125/0605 to 126/0834	OBSAPS_Primary_04_3_4K_DACgain2_4.5knots_Depth57m	Primary 4 sequence at 4.5knots,57m, DAC Gain = 2.0	Primary 4	4.5kts	#11- with replaced transducer	2	100
JD126	Friday, May 6	Transmit P5 to Q10	1004 to 1745	P5-Q10	Primary 5 sequence at 4.5knots,57m, DAC Gain = 2.0	Primary 5	4.5kts	#11- with replaced transducer	2	100
		Q10, Q11, Q12	126/1815 to 127/024	Q10-Q12	Primary 6, at 60m, DAQ Gain =2 for	Primary 6 and Primary 5	Station Stops	#11- with replaced transducer	2	60

Julian Day	Calendar Day	Station Name	Time Interval	Folder name	Test	Program	Speed	J15-3	DAC Gain	Wire-out depth (m)
			7		station stops Q10, Q11 and Q12. Primary 5, at 54m, DAQ Gain = 2 for 2.5knot tows between station stops.		& 2.5kts			
JD 127	Saturday, May 7	Transmit to Q12 to Q13	0306 to 0938	Transit_to_Q13	Primary 5 sequence at 4.5knots,57m, DAC Gain = 2.0	Primary 5	4.5kts	#11- with replaced transducer	2	100
		Q13, Q14, Q15	0953 to 1911	Q13-Q15	Primary 6, at 60m, DAQ Gain =2 for station stops Q13, Q14 and Q15. Primary 5, at 54m, DAQ Gain = 2 for 2.5knot tows between station stops. (*1015 to 1031, 1153 to 1211)	Primary 6 and Primary 5	Station Stops & 2.5kts	#11- with replaced transducer	2	60
		Transmit Q15 to Q16	127/1933 to 128/021	Transit_to_Q16	Primary 5 sequence at 4.5knots,57m,	Primary 5	4.5kts	#11- with replaced transducer	2	100

Julian Day	***Calendar Day***	***Station Name***	***Time Interval***	***Folder name***	***Test***	***Program***	***Speed***	***J15-3***	***DAC Gain***	***Wire-out depth (m)***
			7		DAC Gain = 2.0 (*1933 to 0217)					
JD128	Sunday, May 8									
		Q16, Q17, Q18	0252 to 1130	Q16-Q18	Primary 6, at 60m, DAQ Gain =2 for station stops Q16, Q17 and Q18. Primary 5, at 54m, DAQ Gain = 2 for 2.5knot tows between station stops (*1034 to 1046)	Primary 6 and Primary 5	Station Stops & 2.5kts	#11- with replaced transducer	2	60
		Ambient noise test	1150 to 1206	ambient_test_before_transit_to_P4	Adjusting depths with speed	Ambient noise	Various	#11- with replaced transducer	N/A	
		Transit_to_P4	1214 to 1415	Transit_to_P4	Primary 5 sequence at 4.5knots,60m, DAC Gain = 2.0	Primary 5	4.5kts	#11- with replaced transducer	2	100
					In here we transited back to S5 for the			#11- with replaced transducer		

Julian Day	***Calendar Day***	***Station Name***	***Time Interval***	***Folder name***	***Test***	***Program***	***Speed***	***J15-3***	***DAC Gain***	***Wire-out depth (m)***
					OBS survey					
JD129	Monday, May 9									
		File Size Error test	0708 to 0712	FileSizeError_ Examples	No File Size Error Bench Mark Data set	.1Hz Cos	N/A	N/A	1	N/A
		File Size Error test	071405 to 071805	FileSizeError_ Examples	File Size Error Data set confirms no data loss	.1Hz Cos	N/A	N/A	1	N/A
		Q9_Station _Stop	129/231 5 to 130/011 1	Q9_Station_St op	Primary 6 program for two hours at 60m depth, DAC Gain = 2.0 Storm conditions	Primary 6abc	Statio n Stop	#11- with replaced transducer	2	60
JD130	Tuesday, May 10	Q8_Station _Stop	0235 to 0431	Q8_Station_St op	Primary 6 program for two hours at 60m depth, DAC Gain = 2.0 Storm conditions	Primary 6abc	Statio n Stop	#11- with replaced transducer	2	60
		Q7_Station _Stop	0615 to 0847	Q7_Station_St op	Primary 6 program for two hours at 60m depth, DAC Gain =	Primary 6abc	Statio n Stop	#11- with replaced transducer	2	60

Julian Day	*Calendar Day*	*Station Name*	*Time Interval*	*Folder name*	*Test*	*Program*	*Speed*	*J15-3*	*DAC Gain*	*Wire-out depth (m)*
					2.0 Storm conditions - blown off station and repeated last two programs.					
		Ambient noise at TE	1048 to 1053	TE_ambient_noise_test	Ambient noise test in rough conditions	Ambient noise	Station Stop	#11- with replaced transducer	N/A	60
		TE to TW tow	130/1100 to 131/1040	TE_to_TW_transit/OBSAPS_Primary_Sea_04_3_4K_DACgain2.0_Depth_60m	Very stormy conditions - wind speeds to 48knots on TE to DVLA, then calm conditions from DVLA to TW.	Primary 4	2kts nominal, storm conditions	#11- with replaced transducer	2	60
JD131	Wednesday, May 11	Ambient noise at TW	1042 to 1047	ambient_noise_at_TW	Ambient noise test during rough conditions	Ambient noise	Station Stop	#11- with replaced transducer	N/A	60
		Linearity test at TW	1050 to 1055	OBSAPS_Primary_Sea_CW_1_4K_DACgain2.0_Depth_60m	Linearity test	Primary 4 CW	Station Stop	#11- with replaced transducer	2	60
		Linearity test at TW	1057 to 1112	fadeout_fivetones_fifteenmin_4kHz_DAC	Linearity test	Fade-out test	Station Stop	#11- with replaced transducer	2	60

Julian Day	Calendar Day	Station Name	Time Interval	Folder name	Test	Program	Speed	J15-3	DAC Gain	Wire-out depth (m)
				gain2.0_Depth_60m						
		TSW to DVLA tow	131/1350 to 132/0009	TSW_transit_to_TNE/OBSAPS_Primary_Sea_04_3_4K_DACgain2.0_depth_65m	Primary 4 program towing at 2kts from TSW to the DVLA, DAC Gain = 2	Primary 4	2kts	#11- with replaced transducer	2	73
JD132	Thursday, May 12	DVLA to TNE tow	0016 to 1040	TSW_transit_to_TNE/OBSAPS_Primary_Sea_04_3_4K_DACgain2.5_Depth_65m	Primary 4 program towing at 2kts from the DVLA to TNE, DAC Gain = 2.5	Primary 4	2kts	#11- with replaced transducer	2.5	73
		Ambient noise at TNE	1045 to 1050	ambient_noise_test	Ambient noise test with and without the Power Amp on (this should have no effect but we wnated to check)	Ambient noise	Station Stop	#11- with replaced transducer	N/A	73
		Linearity test at TNE	1059 to 1104	lfm_up_fivemin_4kHz_40-500_DACgain2.0_Depth73m	Linearity test	LFM	Station Stop	#11- with replaced transducer	2	73
		Linearity test at TNE	1108 to 1112	OBSAPS_Primary_Sea_C	Linearity test	Primary 4 CW	Station Stop	#11- with replaced	2	73

Julian Day	***Calendar Day***	***Station Name***	***Time Interval***	***Folder name***	***Test***	***Program***	***Speed***	***J15-3***	***DAC Gain***	***Wire-out depth (m)***
				W_1_4K_DACgain2.0_Depth_65m_part1				transducer		
		Linearity test at TNE	1126 to 1130	OBSAPS_Primary_Sea_CW_1_4K_DACgain2.0_Depth_65m_part2	Linearity test - with the Fluke meter measuring PA current	Primary 4 CW	Station Stop	#11- with replaced transducer	2	73

NOTE:* - XX in the auv extent indicates a problem with the file size, time from file name, or IRIG time. (File was stopped before there was a minimum amount of data.)

Appendix 2: NMEA Log File Description - OBSAPS

The NMEA files contain the gyro and GPS NMEA strings that the Revelle was outputting at approximately a 1 second rate. The GPS NMEA data was generated by the GP150 gps unit and the Gyro NMEA data was generated by the PHINS device. These two RS232 strings were received on 2 separate com ports with the DAQ System PC.

The NMEA file name contains the time stamp for when the file was created. The operator could define a "NMEA File Length (sec)" which would control how many seconds of data each file would contain. At these regular intervals the software would close the existing file and open a new one. The timestamp in the file name is of the following format:

NMEA_Data_%y%j%H%M%S.csv

y = year within century (00-99)
j = day number of the yeare (001-366)
H = hour (00-23)
M = minutes (00-59)
S = seconds (00-59)

At a user defined interval the software will take a 'snapshot' of the current NMEA (GPS and Gyro) strings that had been received on the com ports and write these strings to the NMEA file. A timestamp will also be pre-pended to each new line which is written to file. This time stamp will follow the format stated below:

%y%j%H%M%S%4u

y = year within century (00-99)
j = day number of the yeare (001-366)
H = hour (00-23)
M = minutes (00-59)
S = seconds (00-59)
4U = 4 decimal places of precision for the seconds

The first 5 lines of each NMEA file are filled with a header. Below is an example of that header:

Data Format:
TimeStamp,X,NMEA GGA string,X,NMEA HDT string<cr><lf>
X=Data Valid?
if X=0 : Valid Data
if X=1 : Stale Data

The file's 'Valid Data' or 'Stale Data' (X) indicator was determined by the software depending on the rate at which NMEA strings were received. If the PC does not detect a valid GPS or Gyro

NMEA string within the last 2 seconds the software will set the value 'X' to 1 for the appropriate NMEA string to indicate that the data has gone stale. Otherwise the NMEA string will be considered valid and 'X' will be set to 0. This valid or stale data check also drives an indicator on the Labview program front panel. This is an indicator to the operator to alert them if a problem occurred with either of the NMEA strings such as an unplugged RS232 cable or some other interruption in the RS232 data.

The following is a breakdown of the GPS or (GPGGA string) received from the Revelle and logged to the NMEA files.

$GPGGA, %f,%f,%1s,%f,%1s,%d,%d,%f,%f,%1s,,%1s,,*%s

UTC Time
Latitude
Latitude Sector
Longitude
Longitude Sector
GPS Quality
Number of Satellites
HDOP
Altitude above mean sea level
Altitude unit of measure
Geoidal speration unit of measure
Checksum

The following is a breakdown of the Gyro or (HEHDT string) received from the Melville and logged to the NMEA files.

$HEHDT,%f,%1s*%s

Heading
True or Magnetic
Checksum

Appendix 3: PhilSea'11 J15-3 (S/N 11 & 14) Failures Report and Chronology of Events

Written on: May 12, 2011, Sean McPeak

Prior to the failure of S/N 11:
On Julian day 121 at approximately 22:20 we noticed that one of the transducers was fully depressed inward when we examined the J15-3 on deck just before deployment. We tested the resistance of the J15-3 and it was 70-80 ohms, which was consistent with all our earlier measurements. On deck the other two transducers looked to be the same 3/4" down from the protection grill covering each transducer head. But the STBD rear transducer was noticeably lower than the other two. J15-3 S/N 11 had been working very well for us during the past several weeks of testing on land in a test tank, at the dock in Kaohsiung and at sea on the Revelle during the expedition.

We very briefly ran several CW tones through the J15-3 on deck at extremely low drive levels. All three transducers appeared to work, however at the lower frequencies the STBD read transducer appeared visually and tactilely to be less intense. The combined series resistance of the three coils was roughly the same 75 ohms that we had measured in previous missions as was the RMS current draw, so we decided to continue with the deployment. We were operating with a software DAC gain setting of 2.5 during this portion of the expedition.

On Julian day 122 at approximately 01:06 we detected a failure on J15-3 S/N 11. The PA output current had fallen to 0 amps and the PA output voltage was at the expected nominal level. We brought the J15-3 back on deck. The combined resistance of the J15-3 was measured at roughly 600K.One of the 3 coils had become open circuit instead of the roughly 20 ohms it is supposed to be. On the J15-3 connector, pins 1-2 measured open circuit, pins 3-4 measured approximately 20 ohms and pins 5-6 measured approximately 20 ohms (measurements made by Fluke DVM). We immediately swapped our wet end electronics (pressure sensor, hydrophone and octopus) to the spare J15-3 S/N 14 and re-deployed the transducer and tow body assembly. We then restarted the transmission sequence, but we reduced the software DAC gain to 2.0 for the majority of the remaining expedition. This change was made in order to be more conservative with our drive levels of the J15-3.

The STBD rear transducer was removed from the J15-3 S/N 11 body. This was the transducer that we had noticed to be visibly lower on the previous recovery. Once the transducer was removed we noticed several cups of oil at the bottom of the cylinder. The transducer's impedance was measured again with a Fluke multi-meter after removing it from the J15-3 body and it was very high >300K. We removed the oil, cleaned the cylinder and wired the spare transducer into the assembly. The face seal was cleaned and we reapplied fresh RTV. The spare transducer was then installed and secured into the J15-3 S/N 11 unit. We made sure to match the same polarity as the other two transducers already installed in the J15-3.

Nearly immediately after we swapped to J15-3 S/N 14 on JD122 at 02:43 and began operations we noticed significantly higher current and voltage spikes as measured by both our data acquisition system and a monitor O-scope. The RMS current levels as measured by the power amplifier remained consistent with previous measurements when using the S/N 11 unit. We raised our software current and voltage thresholds significantly to prevent the software's audible warnings from going off. We were suspicious at this point that something was different with S/N 14 but since the power amplifier was NOT over current limiting and its reported RMS current and voltage measurements were roughly the same as previous deployments with S/N 11, we continued with the transmissions.

On JD 123 at 11:24 we experienced an over current shutdown of our power amplifier but were able to restart. We continued to experience frequent software over current and over voltage events and the O-scope monitoring of these channels showed occasionally large spikes on both channels. We continued to watch the situation closely and were increasing in our suspicion that something was not correct with S/N 14.

On JD 124 at 15:08 we experienced an over current event on the power amplifier. We attempted to restart the power amp but had multiple over current events and were unable to resume transmission even at greatly reduced drive levels. We brought the J15-3 S/N 14 on deck and attempted to drive at low levels, but still experienced power amplifier over current shut downs. Since the original J15-3 S/N 11 unit had been repaired by this time with the spare head we swapped our wet end electronics (hydrophone, pressure sensor and octopus) to the S/N 11 unit and re-deployed. The repaired J15-3 S/N 11 unit performed extremely well. There were no more over current or over voltage threshold events detected in the software and the O-scope monitoring these channels looked much cleaner. The power amp also did not have any over current shut down events. The repaired J15-3 S/N 11 continued to perform very well throughout the remainder of the expedition.

The following is a description of the trouble shooting, repair and analysis efforts for J15-3 S/N 14:

On deck the J15-3 S/N 14 drew large amounts of current and caused the Chroma power amps to go into over current protection when a 100V RMS signal was applied across the three coils (J15-3 heads) in series. The Chroma Power amps were set to an over current threshold of 3A for this test. According to the spec sheet the J15-3 has a combined impedance (all three heads in series) of 128.2 ohms @ 200Hz. With a 100Vrms signal applied this should result in 0.78A. We were pulling much more current than what the spec states we should have, so somewhere there was a low impedance path to ground.

We removed all three transducers from the J15-3 S/N 14 unit.

J15-3 SN 14's Head #1 transducer: This transducer had a lot of rust on its base and the cylinder it was in on the J15-3 contained roughly 1 cup of water.

J15-3 SN 14's Head #2&3 transducer: There was not much rust on the base of either of these

transducers.

All three head's in the J15-3 unit measured nearly 0 ohms when the Meg ohm meter was used to check for a ground leaks to sea water from either side of the coil.

The following are the Meg Ohm meter measurements taken using the 250V selection

Head#1:

white to case = 0 Meg ohms
black to case = 0 Meg ohms

Head#2:

white to case = 0 Meg ohms
black to case = 0 Meg ohms

Head#3:

white to case = 0.02 Meg ohms
black to case = 0.018 Meg ohms

All three heads did measure approximately 20 ohms with a Fluke ohm meter used across the individual coils.

Chamber #1 contained roughly 1 cup of sea water - this transducer did NOT have standing water around the top of the head when we examined the J15-3 on deck shortly after recovery. Our theory is that the water drained past the transducer seal which is in contact with the cylinder walls. The failed seal would have allowed the sea water to get into the cylinders.

Chamber #2 contained roughly 1/2 cup of sea water - this transducer did NOT have standing water around the top of the head when we examined the J15-3 on deck shortly after recovery. Our theory is that the water drained past the transducer seal which is in contact with the cylinder walls. The failed seal would have allowed the sea water to get into the cylinders.

Chamber #3 was dry – there WAS standing water around the head of the transducer. Our theory is that the transducer seal was good and prevented water from creeping around it and getting into the cylinder.

Based on the Meg ohm meter measurements and the rust on the back of head # 1 we decided to disassemble this head in the hope that we would be able find sea water or some short to the transducer metal chassis.

We drained all the caster oil from the head, but no sea water was found. We had to un-solder the

wires on the side of the cone which connect to the coil. One of the metal post connections on the metal cone broke off, so we re-expoxy'd it to the cone. We also discovered some of the strands in the short wire sections (which solder between the metal post on the metal cone to the main lead wire post) were broken so these frayed sections were cut off and re-soldered to the post. The head was reassembled and re-filled with the caster oil.

We also drained the sea water from the S/N 14 body and rinsed the chambers and wiring thoroughly. The J15-3 housing was then left to dry for several days. Each connection of the wiring was then tested with a Meg ohm meter to the metal housing of the J15-3. All 6 wire ends measured greater than 500Mohms to the metal chassis.

Head #1,#2 and #3 were tested with a Meg ohm meter. Black to case and White to case were measured on all three transducers when tested on the bench. For all three heads this value was measured to be near 0 ohms with the Meg ohm meter. While at sea we were told, via email by Arlie Farley, that the individual transducers should have greater than 100 Meg ohms or more between black/white wire and the chassis of the transducer. So all three of these heads did NOT meet this spec.

Based on our earlier electrical test of J15-3 S/N 14 on deck, we connected each head individually to our spare PA and very briefly increased the PA output voltage to a level adequate to source 0.8 amps at 200 Hz into the transducer. This current corresponded to the expected current draw with all three heads in series with 100Vrms PA output voltage across the series combination. After proving to ourselves that we could source an individual head with 0.8A without any power amplifier over current events, we then connected all three heads in series and produced a drive signal of 100Vrms @ 200Hz. The current draw was 0.8amps as expected and no power amplifier over current events occurred. For ALL of these tests on the bench we made sure to connect each transducer's metal case to the metal chassis of the Chroma power amps. This connection should have simulated the electrical connection that sea water would make between the transducer case and earth ground. Since all three of these transducer measured low impedance between either side of their coil and chassis ground, it is not clear to us why we were able to successfully drive them with the power amplifier. Even though these transducers passed the bench 100V RMS drive test we are suspicious of how they would function in sea water based on the fact that they don't meet the meg ohm spec we were previously told.

The three transducers were placed back in the S/N 14 unit and wired to all be in phase with each other. The S/N 14 unit was re-assembled and the tow body was reattached. We did NOT use this unit for any other at sea operations during the expedition.

Appendix 4: J15-3 Source Acquisition System Calibration

NI DAQ Measurement of PA Output Voltage

The NI DAQ system measures PA output voltage by monitoring a scaled and isolated version of the amplifier's output voltage. The output amplifier's voltage is taken to a resistive divider network where it is reduced. Then the reduced voltage is isolated by a transformer to prevent any ground loops or 60 Hz hum.

During OBSAPS it was noticed that the Labview software's PA Out Volts rms was always lower than the Chroma power amp's rms measurement of its own output voltage. The Chroma's internal measurement was agreed upon to be very accurate and closely matched a Fluke DVM measuring the same voltage throughout the expedition. There are two reasons listed below which would contribute to the low value of Labview's PA output volts rms readings.

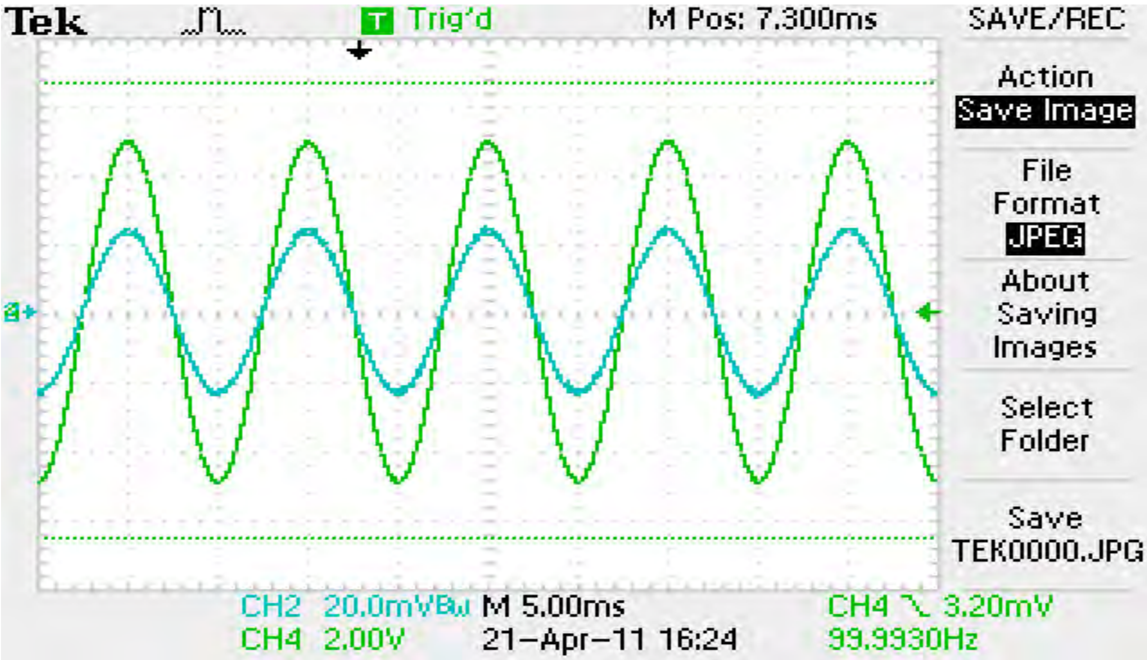
1. There appears to be a roughly 7% attenuation in the voltages measured by the NI DAQ system across all channels. This has been confirmed with an O-scope and using both DAC output as well as an external waveform generator as the signal. There has been significant effort to attempt to understand the root cause of this attenuation in measured voltage:
- The cabling used during the expedition was RG58 and the AM503 was always properly terminated with a 50ohm load.
- All measurements were made as single ended and the NI BNC-2090 breakout box was configured for a NRSE (Non Referenced Single Ended) grounding scheme.
- Experiments were done to change the shield grounding on the BNC-2090 breakout box. There is an internal 'W1' jumper to set the grounding scheme used for the BNC shields. None of the possible combinations made any difference in the measured attenuation.
- After the expedition was complete the NI PXI-6251 was self calibrated by using the NI Measurement and Automation Explorer. This unfortunately also had no effect on the measured attenuation.
- The cable connecting the BNC-2090 device to the PXI-6251 was replaced with a brand new NI SHC-68-68 cable. Unfortunately this did NOT make any difference in the attenuation levels seen.

The cause for the roughly 7% attenuation is not fully understood at this time. However it does seem to be fairly consistent regardless of signal source or frequency.

2. The scaling coefficient determined for the resistive divider network was measured to be 200. This value was determined experimentally based on the following test:
- On April 21,2011 the blue box was calibrated on the Revelle. The calibration factor was set to 200.

- A 10Vp-p @ 100Hz sign wave was input to the blue box using the Arbiter
- The potentiometer was set to get a 200 scale factor for input to output
- As measured by the O-scope: input Vp-p = 9.92V, output Vp-p = 49.6mV to 48.8mV

There was some minor fluctuations in the output measurement made by the O-scope
The green trace is the input signal to the blue scaling box used during OBSAPS
The blue trace is the output of the blue box.



It may have been a better approach to use the Chroma Power amps as the source for a high voltage sinusoid and then compared the output of the resistive divider network with the reading on the Chroma PA for output volts rms. This is still a test that could be done to determine a more accurate value for the correct scaling coefficient to use.

Based on watch stander logs of Chroma PA output volts rms values and corresponding Labview measured PA Vrms a better approximation has been made of the scaling factor for the resistive divider network and isolation transformer.

The approximate 7% attenuation in the NI DAQ volt readings can also be taken into account and compensated for. Compensating for the known NI DAQ attenuation factor and improving the estimate of the resistive divider scaling coefficient can produce a more accurate DAQ system measurement of the PA output voltage which more closely matches the Chroma power. These results can be seen in the 'Voltage Analysis' sheet (Table 1).

NI DAQ Measurement of PA Output Current

The NI DAQ system measures the load current by monitoring the output voltage of the Tektronix AM503 magnetic current probe. The software then scales the output to convert to amps. During the OBSAPS expedition it was noticed that the Labview rms current measurements were always less than those reported by the Chroma power amp.

After looking through test data gathered with a purely resistive load the theory for this discrepancy is as follows:

1. There appears to be a roughly 7% attenuation in the voltages measured by the NI DAQ system across all channels. This has been confirmed with an O-scope and using both DAC output as well as an external waveform generator. There has been signifiant effort to attempt to understand the root cause of this attenuation in measured voltage. The cabling used during the expedition was RG58 and the AM503 was always properly terminated with a 50ohm load. All measurements were made as single ended and the NI BNC-2090 breakout box was configured for a NRSE (Non Referenced Single Ended) grounding scheme. Experiments were done to change the shield grounding on the BNC-2090 breakout box. There is an internal 'W1' jumper to set the grounding scheme used for the BNC shields. None of the possible combinations made any difference in the measured attenuation. After the expedition was complete the NI PXI-6251 was self-calibrated by using the NI Measurement and Automation Explorer. This unfortunately also had no effect on the measured attenuation. The cable connecting the BNC-2090 device to the PXI-6251 was replaced with a brand new NI SHC-68-68 cable, Unfortunately this did NOT make any difference in the attenuation levels seen. The cause for the roughly 7% attenuation is not fully understood at this time. However it does seem to be fairly consistent regardless of signal source or frequency.

2. The AM503 output itself appears to have a percentage error which is dependent on current levels being measured. This phenomenon was measured with a purely resistive load and is shown in the 'Current Analysis' sheet (Table 2). The error was measured by using an O-scope to monitor the output voltage of the AM503 Current probe amp and comparing the readings to the Chroma power amp current measurements. The Chroma current amp measurements were agreed upon to be very reliable. They matched very closely with a Fluke DVM when placed in series with the load.

When both of these errors are taken into account the NI DAQ system current measurements can be adjusted to agree between 1.45% to 2.68% with the Chroma power amp current measurements for values between 0.6 and 2.9 Arms

NI Data acquisition - measured attenuation data

The data sets below (Table 3) show the attenuation present in the NI DAQ system. The cause of this is NOT fully understood. It should be noted that after the NI Measurement and Automation

Explorer self -calibrated the PXI-6251 multi-function DAQ board, the results did NOT change. The NI DAQ system is measuring roughly 7% lower voltage than what is actually present on any one input channel. The input is monitored with an O-scope as the reference. All signals were measured with RG-58 BNC cable which was between 6-10 feet in length. All channels were single ended measurements and the BNC-2090 was set to NRSE ground referenced. The 'W1' jumper internal to the BNC-2090 was adjusted to all three possible positions but this did NOT make any difference. It was left in the factory default position (100 ohms to GND).

It should be noted that the O-scope images of the waveforms have considerably more noise when the NI DAQ system is connected versus. not connected. There are scope images of this. This noise was visible even when NO acquisitions were being made.

Table 1: Voltage Analysis

Voltage Data gathered from watch standers logs during OBSAPS										
The following data was gathered from sections of the watchstanders log sheets										
Known average voltage attentuation for all channels is -7.026%							**Corrected**	**Corrected**		
The data for this is shown on the the attenuation sheet							**Scaling**	**Scaling**		
							Factor	**Factor**	**Scale factor = 224**	
JD122						**Labview**	**if atten. Is**	**if atten is**	**Corrected Labview**	
						Corrected	**taken into**	**NOT taken**	**PA Volts RMS**	
Freq	**Time**	**Fluke**	**Chroma**	**Labview**	**Labview/200**	**for attenuation**	**account**	**into account**	**measurement**	**%error**
77.5	1149	236	234	209	1.045	1.12	208.77	223.92	234.08	0.03
155	1149	240	240	213	1.065	1.14	210.10	225.35	238.56	-0.60
310	1152	242	241	216	1.08	1.16	208.04	223.15	241.92	0.38
							208.97	224.14		
							Corrected	**Corrected**		
							Scaling	**Scaling**		
							Factor	**Factor**	**Scale factor = 224**	
JD 132						**Labview**	**if atten. Is**	**if atten is**	**Corrected Labview**	
						Corrected	**taken into**	**NOT taken**	**PA Volts RMS**	
Freq	**Time**	**Fluke**	**Chroma**	**Labview**	**Labview/200**	**for**	**account**	**into account**	**measurement**	**%error**

						attenuation				
77.5	1006	293	291	261	1.305	1.40	207.90	222.99	292.32	0.45
155		300	300	266	1.33	1.43	210.30	225.56	297.92	-0.69
310		303	303	270	1.35	1.45	209.25	224.44	302.39	-0.20
							209.15	224.33		
							Corrected	**Corrected**		
							Scaling	**Scaling**		
							Factor	**Factor**	**Scale factor = 224**	
JD 126						**Labview**	**if atten. Is**	**if atten is**	**Corrected Labview**	
						Corrected	**taken into**	**NOT taken**	**PA Volts RMS**	
Freq	**Time**	**Fluke**	**Chroma**	**Labview**	**Labview/200**	**for attenuation**	**account**	**into account**	**measurement**	**%error**
77.5	1239	236	234	209	1.045	1.12	208.77	223.92	234.08	0.03
155		240	238	213	1.065	1.14	208.35	223.47	238.56	0.23
310		242	241	216	1.08	1.16	208.04	223.15	241.92	0.38
							208.39	223.52		
Average Scaling Factor if attenuation is NOT taken into account						208.83				
Average Scaling Factor if attenuation IS taken into account						224.00				

Table 2: Current Analysis

Current Data set into Space Heater onboard R/V Revelle								
Both Chroma amps were used in Series and their internal waveform generators were used.								
The frequency of operation was 60Hz for the first portion of this data set where the current								
was being measured into the space heater								
The purpose of this data set was to explore the error between LV reported current v.s.								
Chroma reported current into the load.								
Data was gathered on JD 133								
Known average voltage attenuation for all channels is -7.026%					-7.026	percent		
The data for this is shown on the attenuation sheet								
Col. A	**Col. B**	**Col. C**	**Col. D**	**Col. E**	**Col. F**	**Col. G**	**Col. H**	
	Chroma	**AM503Curr Probe w/50ohm load**	**50*column C**		**LV reported**	**%Error**	**Corrected**	**Corrected Labiew Current measurement**
Chroma	**PA Curr**	**O-scope**	**Calc. Arms**	**Extech**	**Current**	**AM503 v.s.**	**Labview**	**v.s. Chroma Power amp current measurement**
PA Vrms	**Arms**	**Vrms**	**to load**	**Arms**	**Arms**	**Chroma**	**Current**	**%error**
4	0.42	0.00834	0.417	0.35	0.41	-0.714	0.442	5.175040816
6	0.63	0.0125	0.625	0.51	0.6	-0.794	0.647	2.685381708
8	0.84	0.0166	0.83	0.69	0.79	-1.190	0.855	1.775019274
10	1.06	0.0207	1.035	0.87	0.99	-2.358	1.083	2.160986472
12	1.26	0.0248	1.24	1.07	1.18	-1.587	1.282	1.717218947
14	1.47	0.0288	1.44	1.26	1.38	-2.041	1.505	2.389256143
16	1.68	0.0328	1.64	1.46	1.56	-2.381	1.707	1.592170068
18	1.88	0.037	1.85	1.65	1.76	-1.596	1.912	1.688441829
20	2.1	0.041	2.05	1.85	1.95	-2.381	2.133	1.592170068
22	2.3	0.045	2.25	2.06	2.13	-2.174	2.326	1.128615123
24	2.5	0.049	2.45	2.25	2.33	-2.000	2.540	1.612232

26	2.72	0.0531	2.655	2.47	2.53	-2.390	2.768	1.772697016
28	2.93	0.0568	2.84	2.67	2.7	-3.072	2.973	1.455192955
				Average %error =		**-1.898304762**		
The AM503 is set to 0.5A/DIV which equates to 50A/V scaling coefficient								
Chroma PA Vrms: combined series Vrms reported by both Chroma power amps								
Chroma PA Current Arms: rms current reported by the Chroma power amps								
AM503 Current probe output: Vrms as measured by the O-scope with 50 ohm load								
Calc. Current to load: 50 * AM503 Current Probe output								
Extech Arms was reported by secondary magnetic current probe (this was read from a digital display)								
LV reported Current Arms: this was read from the software front panel								
% Error between AM503 v.s. Chroma								
Corrected Labview Current column =			(Col.F*(1+(-Col.G+-F9)/100))					
			This equation takes the LV reported current Arms and					
			adjusts it for the %error due to the AM503 and the attenuation					
			in the DAQ system.					
Summary: The results seem to indicate that when the AM503 %error AND the DAQ attenuation								
%error are taken into account, then the LV reported current agrees much more closely with the								
Chroma reported rms current.								

Table 3: Attenuation Analysis

with NI DAC output through Stanford Research System LP as the source:					
				DAC to	
	DAC to	DAC to	DAC to	Low Pass	
	Low Pass	Low Pass	Low Pass	Filter Out	
	Filter Out	Filter Out	Filter Out	LV meas.	
	O-scope meas.	LV ACH0,1,2	O-scope	ACH0,1,2	
Freq (Hz)	Vp-p	Vp-p	Vrms	Vrms	%error
77	2.04	1.9	1.442	1.344	-6.863
155	2.04	1.9	1.442	1.344	-6.863
310	2.04	1.89	1.442	1.336	-7.353
			Average %error =		**-7.026**
with Analogic as the source:					
	O-scope meas.	LV Meas.	O-scope meas.	LV Meas.	
Freg (Hz)	Vp-p	Vp-p	Vrms	Vrms	%error
80	2.02	1.89	1.428	1.336	-6.436
160	2.04	1.89	1.442	1.336	-7.353
314	2.04	1.89	1.442	1.336	-7.353
			Average %error =		**-7.047**

Appendix 5: Transponder Frequencies

The four Sonatech NT104 acoustic transponders currently in place to measure the motion of the DVLA will remain in place until the OBSAPS DVLA is recovered at the end of the OBSAPS cruise, at which time they will also be recovered. The transponder transmit frequencies are:

XMIT: 11.0, 11.5, 12.0, and 12.5 kHz (received by the D-STARs)
XMIT-JITTER REDUCTION: 10.0 and 13.0 kHz

The D-STAR interrogation frequencies are:

XMIT: 9.0 kHz (received by the transponders)
XMIT-JITTER REDUCTION: 10.0 kHz

Benthos 865A/DB13 acoustic releases are used on the OBSAPS DVLA. The release frequencies will be:

Release #1:
RCV: 8.5 kHz
XMIT: 9.5 kHz

Release #2:
RCV: 10.5 kHz
XMIT: 11.0 kHz

The OBS program uses Edgetech/ORE transponders that transmit from the ship at 11KHz and respond from the OBSs at 13KHz.

Appendix 6: Notes on OBSAPS Bathymetry

Tom Bolmer
Tuesday, October 11, 2011

To make a bathymetry map for the OBSAPS cruise on the Revelle (RR1106) a search was made on the web to get as much multibeam data as could be found. Some data was acquired from communications with others. Unfortunately none of these data files were post-processed to remove erroneous peaks. The data also had various levels of Sounding Velocity Profiles (SVP) applied. Some cruises seemed to have ignored the need for these SVPs to be applied as the water masses changed. As a result, there was a need to be choosey about how data were used.

The data sets available for use were:

Ship	*Cruise*	*Source*
Kilo Moana	KM0910	Scheer
Roger Revelle	RR1005	Worcester
Roger Revelle	RR1009	Worcester
Roger Revelle	RR1104	Worcester
Roger Revelle	RR1105	Worcester
Roger Revelle	RR1106	OBSAOS
Melville	MV0905	Worcester
Melville	MV0906	Worcester
Melville	MV0907	Worcester
Melville	COOK11MV	NGDC
Ewing	EW9509	NGDC
Ewing	EW9510	NGDC
Marcus Langseth	MGL0909	LDEO
Robert Conrad	RC2611	NGDC

The OBSAPS cruise, RR1106, was post-processed at sea for spikes and bad points. The Kilo Moana (KM0910) data in the region of the ODVLA out to at least 25 kilometers from the ODVLA was also post-processed before going to sea for the OBSAPS cruise. The rest of the data were from the other assembled cruises and were not post-processed.

Two giridded data sets were created from these data sets. a) A large OBSAPS regional grid at 125 meters spacing for the OBSAPS operational area (see Figure 1). B) A smaller area, that went out a bit more than 25 kilometers from the ODVLA, was gridded at 50 meters (see Figures 2 & 3).

125 meter grid spacing

For the larger general region the data were gridded in several groupings and then each grid was overlaid on another grid. The "better" data sets were given precedence over "less good" data sets. All of these grids were done at 125 meter grid spacing.

Grid 1 used:
- RR1005
- RR1009
- RR1104
- RR1105

Grid 2 used:
- KM0910

Grid 3 used:
- EW9509
- EW9510
- MGL0909
- MV0905
- MV0906
- MV0907
- COOK11MV
- RC2611

Grid 4 used:
- RR1106

Grids 1 and 2 were merged with Grid 2 getting precedence. This grid was merged with Grid 3 and had precedence over Grid 3. Finally, this last grid was merged with Grid 4, which had precedence. The resultant third merged grid was then turned into ASCII XYZ data where data existed. This data was re-gridded at 125 meters spacing. Where there was no multibeam data the Smith & Sandwell gravity derived World Topography version 13.1 was used. All of the larger regional plots in the Cruise Report (areas greater than the 25 kilometer circle around the ODVLA) used this grid for bathymetry.

Figure 1 shows the 125 meter grid for much of the OBSAPS operational area. Note the "smoother" areas where the Smith and Sandwell data have been used. This grid was used during the cruise to get "nominal" depths for the OBSs (Table 6 of the Cruise Report).

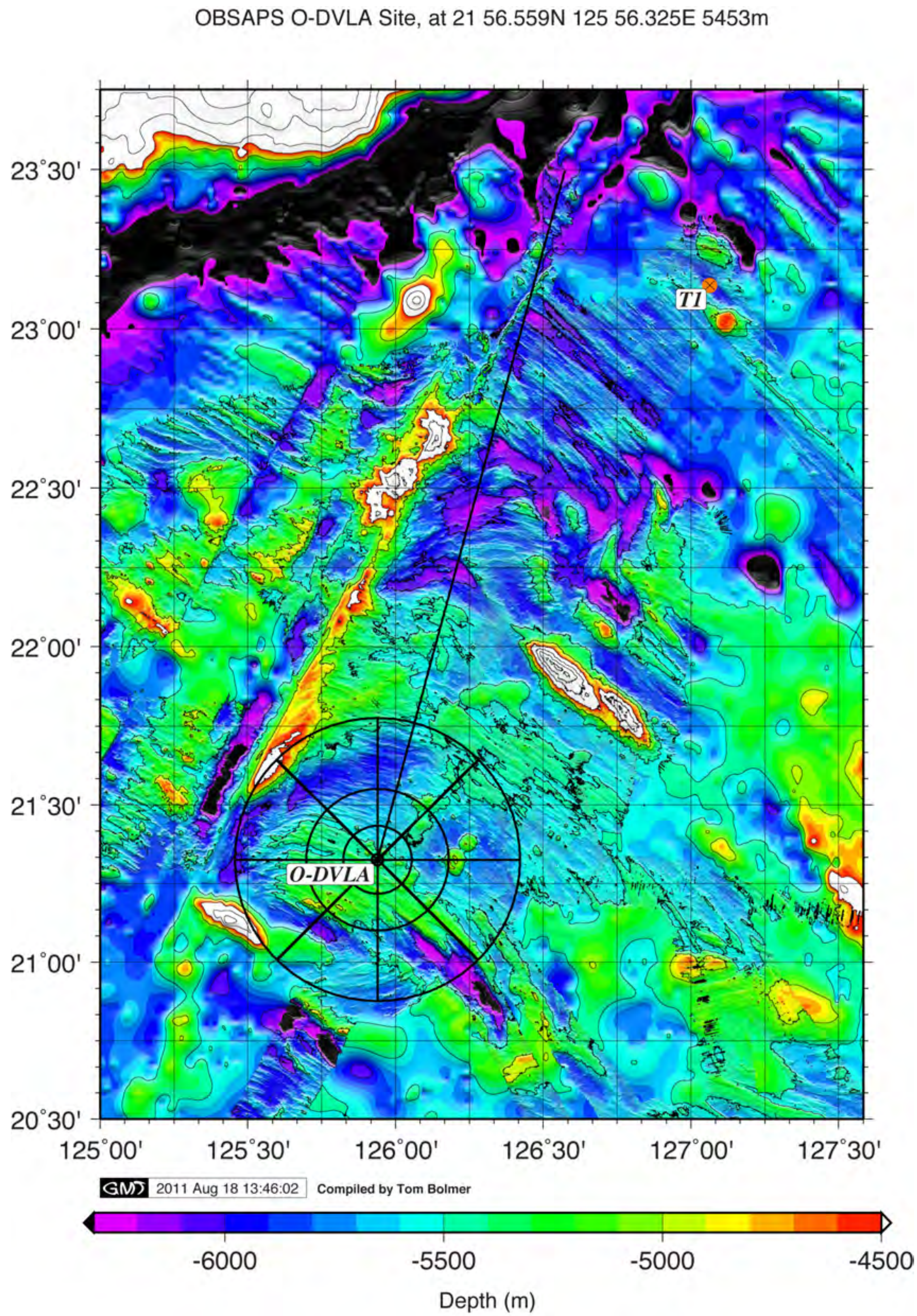


Figure 1: The large OBSAP regional grid at 125 meters is shown here.

50 meter grid spacing

For the 50 meter grid spacing a smaller set of data were used since the KM0910 and RR1106 data covered the 25 kilometer circle area so well. These data were post-processed. This data was gridded at 50 meter spacing to try and get a better understanding of the area near the ODVLA. When creating this 50 meter spaced grid the two cruises were gridded together unlike the process for creating the 125 meter spaced grid. This grid spacing is pushing the multibeam data to it's limits. But, the numerous overlapping tracks in the area constitute a dense data set and it was reasonable to grid at 50 meter spacing.

Figure 2 shows the 50 meter spacing grid. Even though there is good agreement with the RR1106 and KM0910 data in this grid, one can see some of the individual multibeam swaths showing in the plot. This grid should be used in the future to get depths to instruments in known geographic locations (see the Table below).

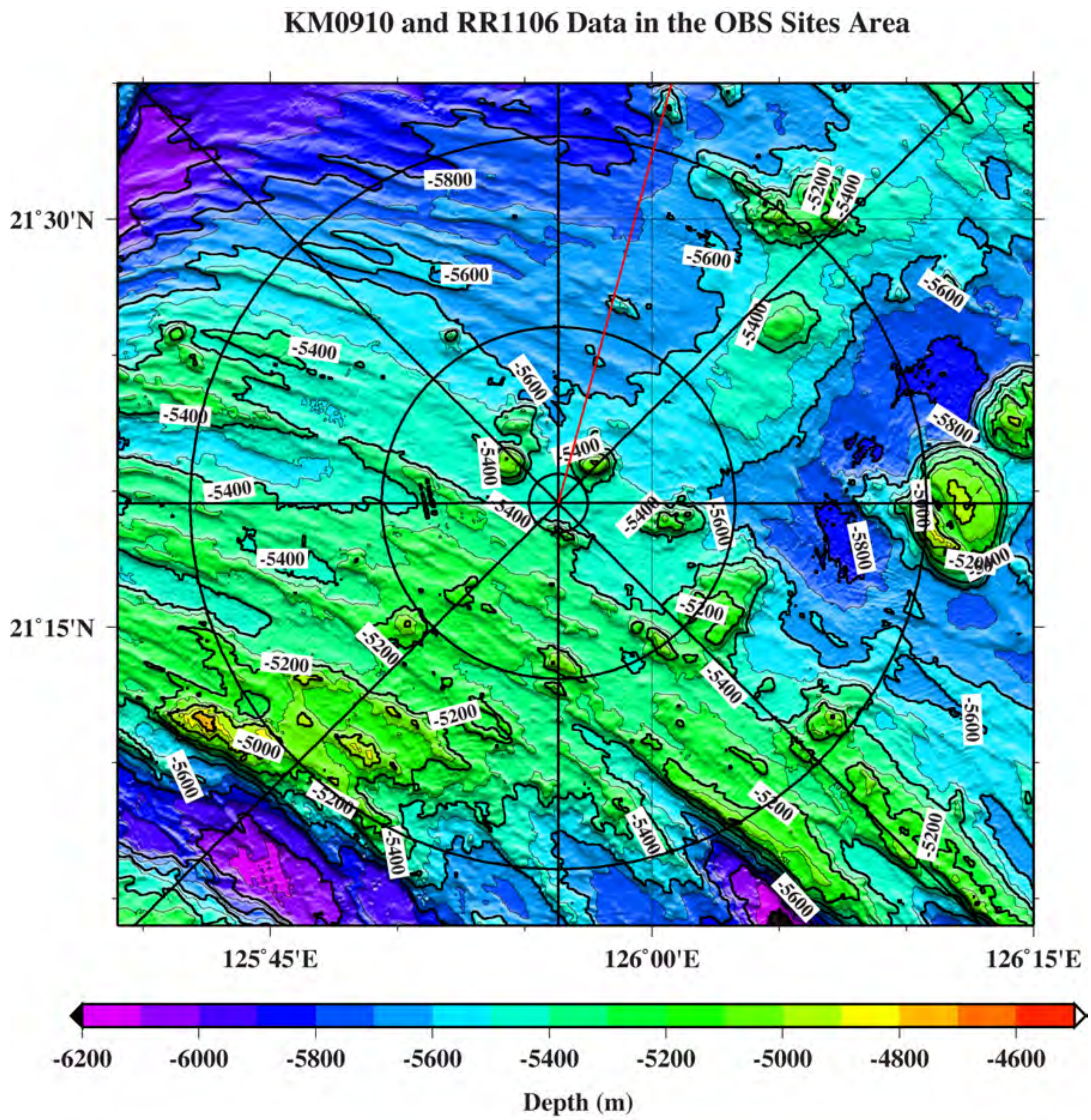


Figure 2: This shows the 50 meter gridded data around the ODVLA with the 2, 12, and 25 kilometer circles overlain. This was created using only the KM0910 and RR1106 multibeam data.

The 50 meter grid shown in Figure 3 below is included to show the area around the 2 kilometer circle, where the OBSs were deployed. This figure uses a grid based only on the RR1106 multibeam data.

OBSAPS RR1106 MB in OBS area at 50 meters

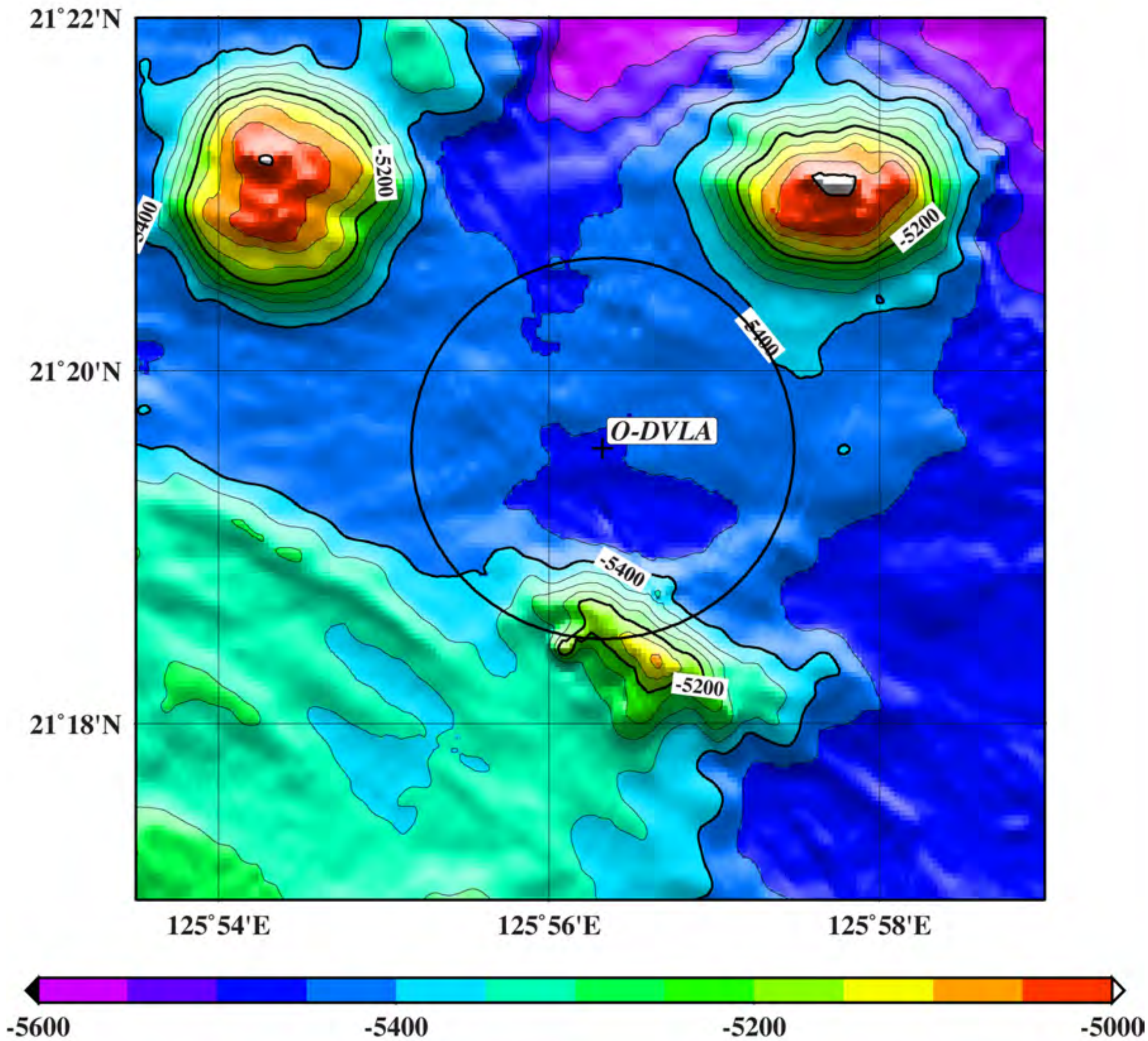


Figure 3: The bathymetry shown here uses only the RR1106 (OBSAPS) multibeam data and is gridded at 50 meters. A 2 kilometer circle is shown around the ODVLA. Adding the KM0910 data (as used in Figure 2) to this grid does not change the bathymetry significantly.

Depths for Instruments

The 50 meter grid spacing bathymetry file shown in Figures 2 & 3 was used to find the depths shown in the Table below at the OBS and ODVLA locations. The GMT program grdtrack was used to read an ASCII XYZ file with the latitude and longitude locations for these sites and interpolate the gridded data for the requested locations.

The command used was:

```
grdtrack sites_081911.dat
    -G/Atigun1/Data/Phil/Bathy/mb/KM0910/plots/KM_RR_50meters.grd
```

Site	*Latitude*		*Longitude*		*Depth**	*Depth***	*Nominal****
	Deg.	*Minutes*	*Deg.*	*Minutes*	*Meters*	*Meters*	*Depths*
ODVLA	21	19.5594	125	56.3247	5451.64	5433	5438
OBS-1	21	20.8316	125	56.1601	5450.97	5447	5452
OBS-2	21	19.5370	125	57.5100	5422.10	5411	5416
OBS-3	21	18.2867	125	56.4779	5225.88	5214	5219
OBS-4	21	19.5387	125	55.1455	5430.45	5232	5437
OBS-5	21	18.5955	125	57.4424	5449.98	5447	5452
OBS-6	21	18.7481	125	55.4552	5394.80	5395	5400

* Based on the 50 meter grid spacing as described above.
** Based on the 125 meter grid spacing done at sea and the same as the "OBS Surveyed Sites" in Table 6 of the Cruise Report.
*** Determined from the 125 meter grid by adding 5 meters as described in Section 5.0 of the Cruise Report.

The differences in depths of the last three columns of the Table give an indication of the variance in the depth estimates based on different multibeam bathymetry and on different methods for creating the grids. If we need faithful bathymetry with less variance, another round of careful multibeam processing will be necessary.

A comparison of the depths derived from the KM0910 and RR1106 grid (Figure 2) versus those derived only from the RR1106 grid (Figure 3) showed agreement within less than a meter. Figure 4 below shows a coarser grid (250 meters) created by Steve Lynch (email on April 12 from Peter Worcester), which uses multibeam data from previous years' cruises. When this grid was used to find the ODVLA and OBS depths, the depths differed from 14 to 37 meters relative to the depths in the Table above for the 50 meter gridded data.

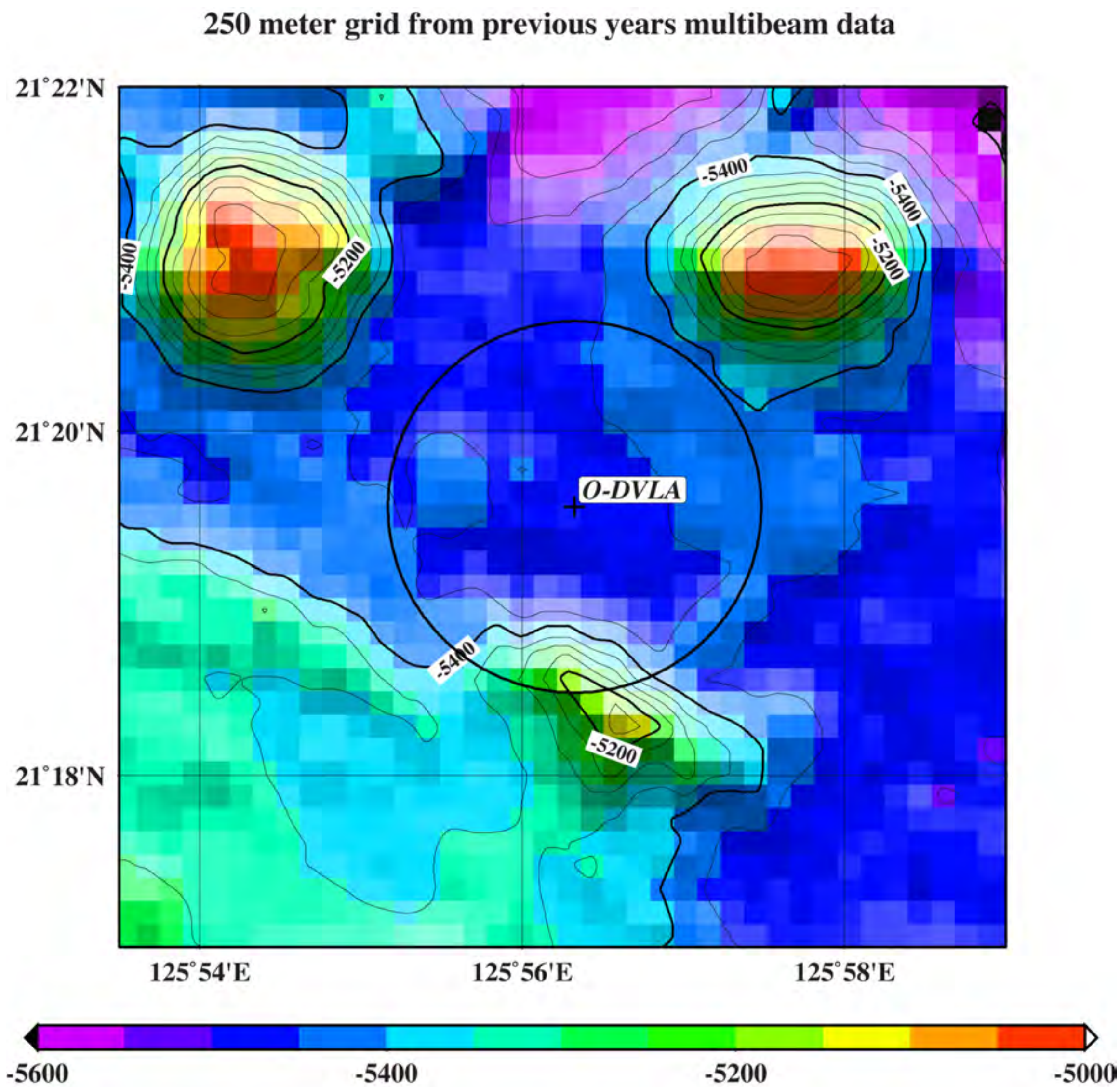


Figure 4: This shows the same area as Figure 3 but uses a 250 meter gridded data set, created by Steve lynch. This grid uses multibeam data from previous years' cruises.

Appendix 7: Thoughts for Next Time

Here is a short list of things to think about if we are doing another experiment similar to OBSAPS:

1) Be sure to always check the J15-3s in a test tank before sending them to sea. "Meg" the electrical connections to the case to check for leakage in the insulation and shorts to ground (see 2 below). Check that the resistance of the coils is correct. It might even be an idea to pull at least one cylinder on each J15-3 to check for corrosion, salt water and loose wiring.

2) It would be useful to meg an unused and calibrated J15-3 head (coil to case) to get a good bench mark of what the resistance to ground should be. On OBSAPS there was a discrepancy between what we were measuring with the megohm meter and what NUWC was telling us we should be seeing. This was with J15-3 heads that were proven to be functional yet meg'd significantly lower than the NUWC spec. Use the megohm meter to measure a new spare head and J15-3 after receiving them from NUWC and before actually using them at sea. Bring a Meg ohm meter to sea.

3) For underway tows it would be better to use an armored cable rather than the braided cable we used. (John Kemp's recommendation.)

4) On station, in heavy seas, the J15-3 spins on the end of the cable which results in twisting and possible hockling of the cable. It would be best to have a swivel at the top of J15-3 (with the necessary electrical slip rings). Alternatively have a special J15-3, without fins, for station stops.

5) There should be analog, anti-aliasing filters on all six channels going to the ADC in the Labview acquisition system.

6) The Labview system should be calibrated and tested, in the lab, to ensure that it is properly recording true voltage and current levels.

7) Confirm the relationship between SPL and current for each J15-3. Is the current measure peak-to-peak or RMS? The confusion and mixed info we were getting specific to the RMS current versus peak-to-peak current rating was unfortunate. A broader issue, however, is how to really tell when one is over-driving the J15-3. We looked at the harmonic content in the H-91 signal as an indicator of distortion, but that is a tricky measurement to reliably make.

8) We felt we needed two Chroma power amplifiers to adequately drive the J15-3 at its maximum specified current level. Although the 2 power amplifiers performed reasonably well in series, we had trouble getting the two amps to recognize that they were sync'd together (master/slave) when the Vref input voltage was selected (ie inputting a user defined signal. like our M-sequences, rather than using the internal waveform generator). We worked around this by enabling and then disabling the amps' internal waveform generator. Somehow this allowed the amps to function in the series sync'd mode with the Vref as the input signal. It would be nice to

get some information from Chroma on how to avoid that step if at all possible.

9) Remember that if the H91 amplifier is on top of the Chromas, then the Chromas will add noise to the H91 channel.

10) We should bring a small speaker/amp with cabling to allow us to listen to the tones going into the source.

11) We should have a sound card installed in the DAQ system so we could drive a set of speakers for louder audible software alarms.

12) Bring along a purely resistive load for testing the power amp, if necessary. We made the ship's portable heater work well enough for this purpose.

13) The voltage scaling coefficient for the "blue box" should be determined with a higher input voltage, if possible. On OBSAPS we used the 20V peak output of the waveform generator for the input voltage. I we were to do it again we would use the Chroma output with a sine wave Vref input signal set to a suitable voltage to get a few hundred volts at the output of the amp. Then we would use the Fluke as well as the Chroma itself to measure the voltage applied to the "blue box" and we would use the Fluke meter, as well as perhaps the scope, to measure the divided down voltage that the DAQ input would see. Due to the high attenuation factor, the higher input voltage to the "blue box" would be a better determination of the scaling coefficient.

Appendix 8: OBSIP Report

Ernest Aaron
SIO
May 15, 2011

Cruise:	Stephen (RR1106)
IRIS Network Code:	Not available
Purpose:	Deploy and Recover 2 LP & 4 SP OBS (SIO)
Vessel:	R/V Roger Revelle
Ports:	Kaohsiung, Taiwan
Master/Captain:	Tom Desjardins
Chief Scientist:	Ralph Stephen, WHOI
Deck Operations:	John Kemp, WHOI Mooring Group
Data Management:	Tom Bolmer, WHOI
SIO Engineer:	Scott Carey
SIO Technician:	Ernest Aaron
OASIS:	Richard Campbell, OASIS Inc.
Development Engineer:	Sean McPeak, APL-UW.
Grad Student:	Brianne Moskovitz, SIO
Cruise Dates:	(04/19/11 – 05/16/11)

R/V ROGER REVELLE

(I) Summary of OBS Lab Activities
(II) Instrumentation
(III) Areas of Concern
(IV) Ships Equipment and Condition
(V) Journal of Events (Chronological)
1 Loading & Setup
2 Transit
3 Acoustic Rosette Test
4 OBS Deployments
5 OBS Survey/Relocations
6 OBS Recoveries
7 Cruise Summary
8 Data Processing
9 Charts, Graphs & Sketches

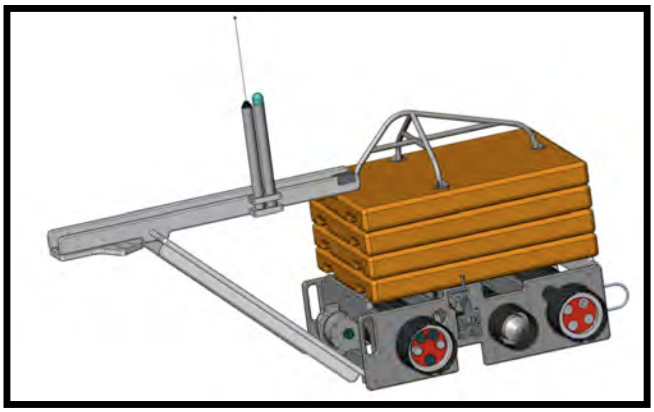
I. Summary of OBS Lab Activities

The Stephen cruise RR1106 consisted of six total deployments and recoveries. Two of the OBS were of the syntactic broadband design and four were short period OBS. The instruments were located in the Philippine Sea east of Kaohsiung, Taiwan. The broadband OBS used 240 second Trillium seismometers (T240) and the short period OBS used three-component geophones.

II. Instrumentation

SIO LC4X4, LP-OBS (Broadband)

The Institute of Geophysics and Planetary Physics at Scripps Institution of Oceanography (IGPP/SIO) in conjunction with the Ocean Bottom Seismograph Instrument Pool (OBSIP) provided 2 long period LC4X4s for this experiment. The sensors on these long period LC4X4s are a Trillium 240 (T240) seismometer, and a differential pressure gauge (DPG). Each instrument consists of an anchor, a modular four-piece syntactic float assembly on which the lifting bail is attached. A polyethylene (HDPE) frame holds the acoustic release transponder the data logger, the battery bottle, and a dual mechanical release system.

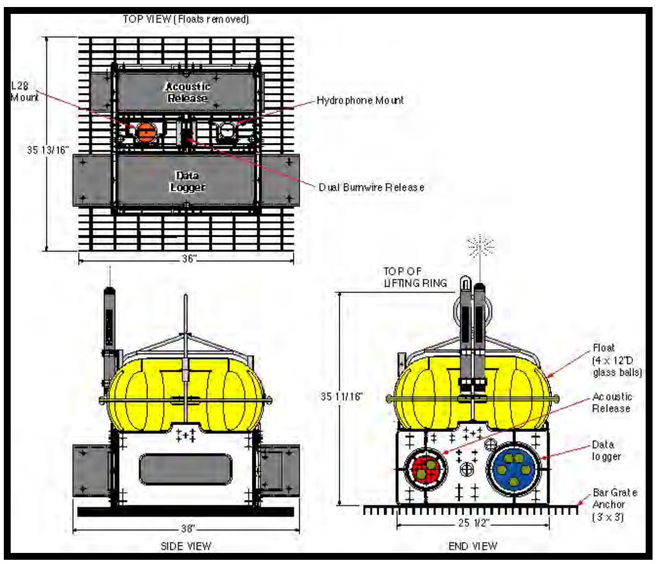


The float and frame components are preassembled and secured to a pallet. The Trillium seismometers are stored independent of the frame, and are attached and tested prior to deployment. The complete instrument weighs approximately 1000 pounds in air (deployment weight). The anchor is a 200-pound steel plate held to the base of the poly frame by an AmSteel lanyard drawn through two stainless U-bolts mounted to the anchor. Two release mechanisms are utilized at either side of the lanyard. After the anchor is released for recovery the OBS becomes positively buoyant and begins to ascend to the sea surface at a rate of approximately 45 meters/min. To increase visibility at the surface, an orange flag on a 48” fiberglass-resin staff is attached to the sensor ball support arm along with a Novatech low-pressure activated strobe-beacon and radio. The radio provides one-second pulses every two-seconds at 160.725 MHz.

SIO LC4X4, SP-OBS (Short Period)

The Institute of Geophysics and Planetary Physics at Scripps Institution of Oceanography (IGPP/SIO) in conjunction with the Ocean Bottom Seismology Instrument Pool (OBSIP) provided 4 short period LC4X4s for this experiment. The sensors used on the SP-OBS are an L28 gimbaled 3-component geophone, and a hydrophone. Each instrument is comprised of a 100-pound anchor, a four ball McLane glass float assembly on which the lifting bail is attached, two syntactic foam blocks are added for additional floatation to aid positive buoyancy, and a polyethylene (HDPE) frame holding the sensors, an acoustic release transponder, an LC4X4 data logger, and a central mechanical release system.

The SP-OBS float and frame components are typically stored separately in a custom rack system, and are assembled and tested prior to deployment on a raised preparation platform, which is secured to the deck. The complete instrument weighs approximately 300 pounds in air. The anchor is a 100-pound iron grate held to the base of the poly frame by a single 2” oval quick-link when the release mechanism is cocked and secured. When the anchor is released for recovery, the four 12” glass spherical floats, as well as the syntactic foam blocks provide sufficient buoyancy to lift the instrument at about 45 m/min to the sea surface. To increase visibility at the surface, an orange flag on a 48” fiberglass-resin staff is attached to the side of the lift bale along with a Novatech low-pressure activated strobe-beacon and radio. The radio provides one-second pulses every two-seconds at 160.725 MHz.



The acoustic release transponder developed in conjunction with ORE/EdgeTech is comprised of a main circuit board, a SIO developed battery array, and an ITC-3013 transducer manufactured by International Transducer Corp. These are all installed in and on a 4-5/8” aluminum pressure case. All SIO transponders are interrogated at 11kHz and respond at 13kHz. Alkaline batteries provide 18 volts power for the burn, 12 volts power for the transponder, and 9 volts power for the circuit board logic. The release mechanism includes two double wire burn elements. When fresh, two battery strings are combined to provide the 18 volts to burn one of two release wires in an average of 7 minutes for water depths encountered during this experiment.

III. Areas of Concern

Operational time, typhoon, and end of cruise time for processing data are the main areas of concern as I see it.

John Kemp discovered that the Revell trawl-winch hydraulic pump resonates at ~11kHz and causes any enabled acoustics, designed for interrogation at 11kHz, to chirp wildly (approx every second) as long as the pump is running.

IV. Ships Equipment and Condition

Excellent.

V. Journal of Events in Chronological Order

All times and dates in this report are local Taiwan time unless otherwise noted

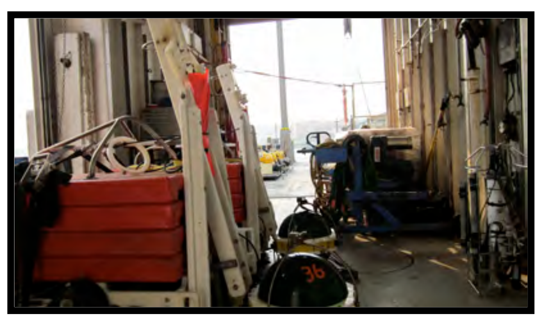
1. Loading & Setup

04/18/11

The Scripps 20' container cleared Taiwanese Customs and was scheduled to be delivered to the ship on the 19th.

04/19/11 08:00

The container was delivered and promptly unstuffed.

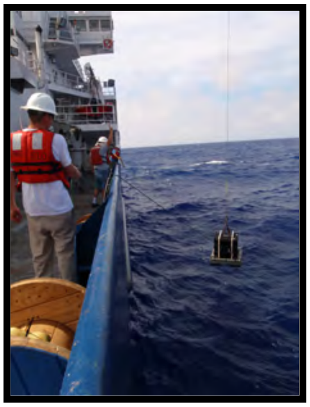


04/19/11 13:00

I was just informed that the cruise has been delayed due to engine issues. The USCG just finished an inspection and determined that two of the diesel engines have lifters and cams that are out of specification. The delay duration is currently unknown.

2. Transit
04/29/11 16:00 Local
We finally departed the Kaohsiung dock and we expect to be at the acoustic rosette test site about 06:00 (Local) on the 29th.

3. Acoustic Rosette Test
2011:119:22:12:00
Rosette deployed, unit 122 was successfully enabled at 50 meters. Max payout set at 4000 meters. Unit 86 would not accept a disable command until the rosette was retrieved to ~3500 meters.



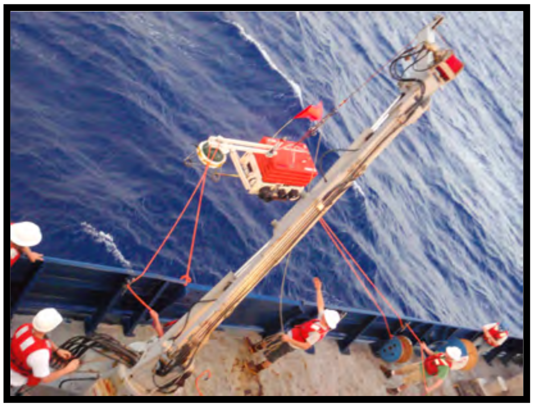
During the retrieval, we snagged a long-line and the fishermen got a little aggressive as we attempted to untangle it from the wire. Ultimately we had to cut it free because they were simultaneously retrieving it, which was creating unsafe tension on the fishing line.

4. OBS Deployments
OBS4 (L28+HYD) 5431 Meters
UTC 2011:120:20:21:00
We used the starboard Alaskan crane to perform the deployments. This procedure went without flaw. I disabled the acoustic at ~200 meters depth, so that we could move quickly to the next deployment site. External hydrophone added.

OBS6 (T240-36) 5398 Meters
UTC 2011:120:21:08:00
I double-checked the battery bottle power leads through the logger to the sensor ball and everything checked fine. I also burned off the passivated layer on the lithium's before checkout. The deployment went very smoothly. The new 200# anchor balanced the OBS nicely and did not pull away from the frame, as was the concern.

OBS3 (L28+HYD) 5077 Meters
UTC 2011:120:20:50:00
Smooth deployment. External hydrophone added. We attempted to deploy this OBS on top of a seamount.

OBS5 (T240-44) 5405 Meters
UTC 2011:120:22:46:00
I burned off the passivated layer on the lithium's before checkout. The deployment went smoothly. Again, the anchor plate held firm to the OBS base.

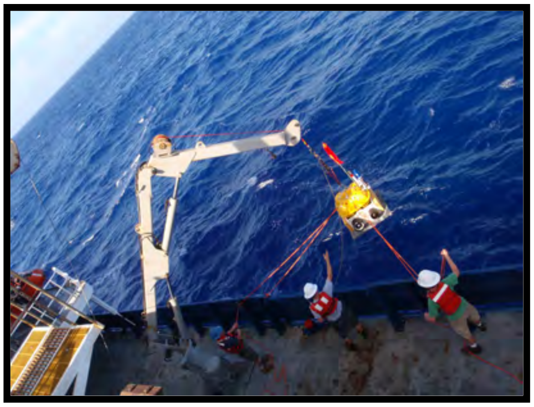


OBS2 (L28) 5423 Meters
UTC 2011:120:23:25:00
This SP OBS has a swing pin release, which I set-tension by hand. I intended to convert two of the replaced swing pin releases into a drop pin, but the resulting release was way too sloppy and would not hold a drop pin under tension.

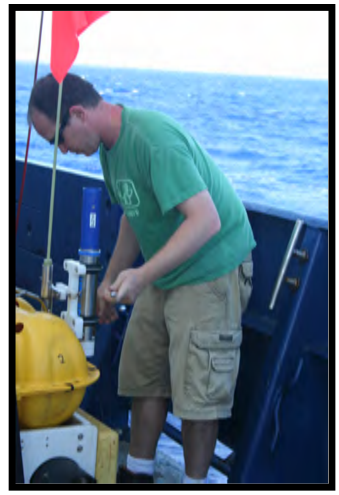
Smooth deployment. No external hydrophone on this instrument.

*This logger may have a missing seal screw on the vacuum port as I found an unaccounted for seal screw on the checkout table during the next logger setup. Obviously, I hope this is not the case, but I will not be sure until the recovery phase. I immediately brought this to Ralph's attention and documented the concern.

OBS1 (L28+HYD) 5440 Meters
UTC 2011:120:00:19:00



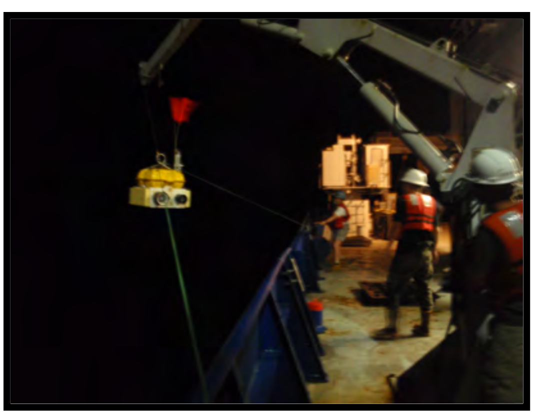
Smooth deployment. External hydrophone added.



5. OBS Survey/Relocations
2011:129:03:00:00 (TFOM4 confirmed)
I was able to complete the survey of all six OBS in just over 6-hours. Six of the eighteen stations were oriented to allow two positions (24-total) to be interrogated, which made the survey procedure more efficient. (See OBS Survey map in section 9)

Station 15 was the only position that we had no initial communication with the acoustic. This shadow issue was overcome by transiting towards the OBS release position.

6. OBS Recoveries
OBS2 (L28) 5423 Meters
UTC 2011:132:16:15:00
This OBS has a swing-pin release. It successfully released from its anchor about 7-minutes into the first burn #1 cycle.



This deployment sight is also where I suspect that I forgot to reinstall the seal screw cap over the vacuum port.

The rise rate based on slant-ranges is ~30 meters/min, which is slower than expected.

The seal screw was missing. Logger 75 was flooded and is dead. I removed all alkaline batteries, which were corroded and slightly off-gassing, for safe disposal. I rinsed out the logger guts with fresh water and dried it as much as possible for the conditions.

OBS3 (L28+HYD) 5077 Meters
UTC 2011:133:03:18:00
This OBS released on the first burn #1 cycle. The rise rate based on the slant-ranges is ~44 meters/min.

It was a smooth recovery. We have a good time tag and the data is currently downloading.

OBS4 (L28+HYD) 5431 Meters
UTC 2011:133:08:20:00
Logger 87 had what appears to be a low-pressure leak, or a small leak during ascent at recovery. There was less than a palm full of water in the bottom of the logger case, but it was enough to short out the 4x4 computer. The clock was dead, so I could not get time. The rear and front end-cap/bore-seal o-rings were clean, undamaged and did not have water in their grooves. The vacuum port seal screw was dry on the inside. The rear end-cap does not have plugs, or seal screws. The desiccant packs had not reacted, and were loose and dry. I removed the battery packs and the three main batteries had moisture at the base, but all three had 8.27V measured on the Fluke multimeter. The clock-pack was a little wet on the outside, but showed 3.24V. The water could have splashed around during recovery and from carrying it into the lab. I then removed the logger tray from the case and slowly turned it vertical and a couple of drops of water came out of the run-plug bore from the inside of the end-cap. The other sockets appeared dry. Again, this water could have gotten in the run-plug bore from the angle that I carried the logger into the lab.

The compact flash (CF) cards have the expected amount of data on them (16.38 gigs) and it is currently being backed up.

OBS3 (L28+HYD) 5077 Meters
UTC 2011:133:08:52:00
This instrument released during the first minute of the second burn #1 cycle. Acoustic 55 has a 5-minute burn cycle and required a little more time to release.

It was another smooth recovery. The logger had a good tag and the raw data is being copied.

OBS6 (T240-36) 5398 Meters
UTC 2011:133:22:02:00
The OBS released from the anchor approximately 8-minutes into the first burn #1 cycle.

Smooth recovery. The logger had good time and the CF has the appropriate amount of raw data.

OBS5 (T240-44) 5405 Meters
UTC 2011:134:00:36:00
This OBS released from the anchor approximately 6-minutes into the first burn #1 cycle.

The recovery was flawless. The logger timing was good and the raw data size is correct.

7. Cruise Summary

Overall, this was a very good cruise. The only loss in data was due to a personal mistake where I forgot to reinstall the vacuum port seal screw for logger #75. The only other incident was that logger #87 experienced a low-pressure leak during its ascent to the sea surface. Fortunately, all of the anticipated data was there, but I was unable to get timing. Ralph stated that he should be able to matchup the events recorded on the external hydrophone, which collected data independent of the OBS 4x4 logger.

Back row (L2R): John, Scott, Richard, Ralph, Ben, Brianne
Front row (L2R): Sean, John, Ernie, Tom

I was unable to provide psegy to Ralph before the end of this cruise because I recently discovered that these loggers have a different code written to the CPU and our labs current processing software will not read this new code.

8. Data Processing

2011:133:09:00:00
Phil,
I tried to process the first dataset to psegy and ran into an issue as the channels were beginning the channel split.

Cannot read the rawFilename '/Volumes/DATA/psegy/obs1/raw/obs1.obs'.
Command ended.
Exit Value: 1Done!

2011:133:22:00:00
I received word from the lab (Phil) that the processing software I have will not work on these loggers data. They will attempt to rewrite the code to work with this dataset and get it to me before the end of the cruise.

Email: Phil Thai [pthai@ucsd.edu]
Sent: Friday, May 13, 2011 10:39 AM
To: Aaron, Ernest
Ernie,
We realized that since those loggers got new code for the cpu the processing code has to be rewritten. You aren't going to be able to process with your current version of the processing software.

We will work on the new software and forward it to you as soon as it is done.

-phil

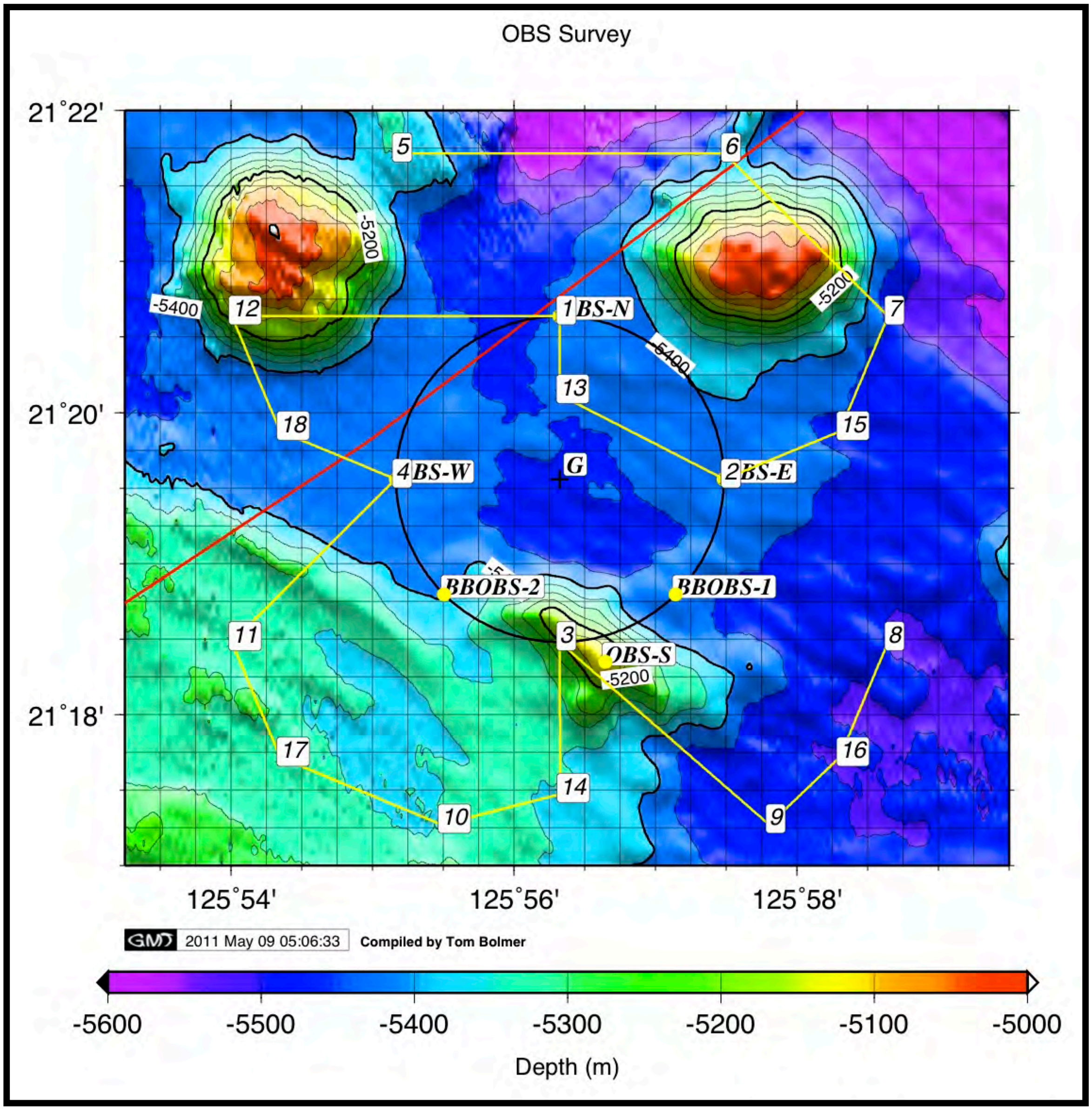
9. Charts, Graphs & Sketches

site	ac	logger	sensor	hyd	synch time	wake up time	drop-LAT	drop-LON	rec-LAT	rec-LON	depth
OBS4	84	SP87	L28	HM167	2011:120:01:59:00	2011:120:20:00:00	21.32596	125.91938	21.32560	125.91910	5431
OBS6	122	LP103	T240-36		2011:120:01:35:00	2011:120:22:00:00	21.31325	125.92508	21.31250	125.92430	5398
OBS3	55	SP13	L28	HM168	2011:120:21:27:00	2011:120:22:00:00	21.30585	125.94410	21.30480	125.94130	5077
OBS5	39	LP108	T240-44		2011:120:22:19:00	2011:120:23:00:00	21.31326	125.95240	21.30990	125.95740	5405
OBS2	139	SP75	L28		2011:120:23:00:00	2011:120:23:30:00	21.32596	125.95805	21.32560	125.95850	5423
OBS1	50	SP73	L28	HM169	2011:120:23:56:00	2011:121:00:30:00	21.34395	125.93875	21.34720	125.93600	5440

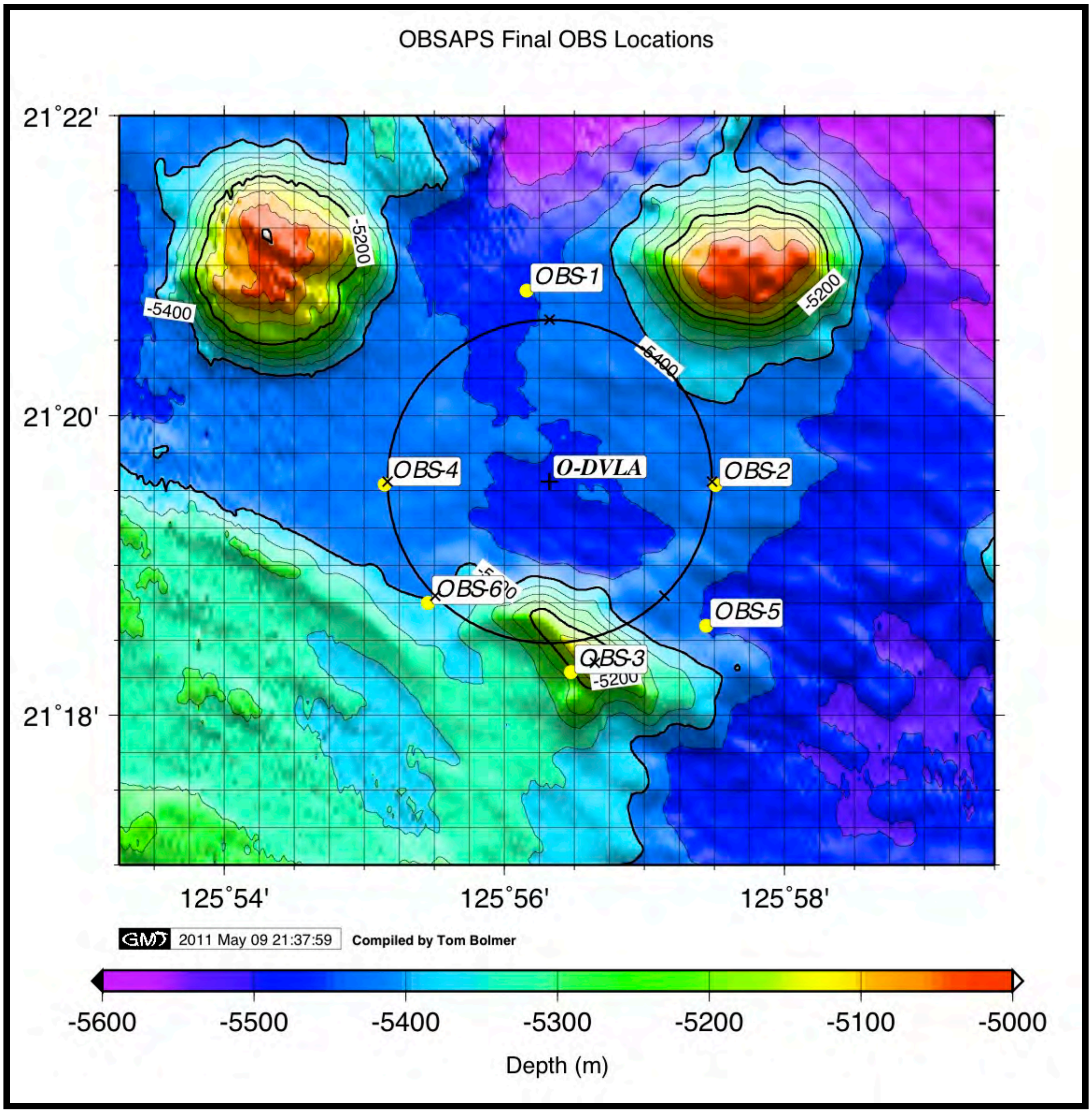
OBS deployments in order of operations

site	logger	sensor	gigs raw	comments
OBS1	SP73	L28+HYD	15.99	Drift: 0.0289716
OBS2	SP75	L28	0.00	Logger leaked due to a missing vacuum port seal screw.
OBS3	SP13	L28+HYD	16.43	Drift: -0.019779
OBS4	SP87	L28+HYD	16.38	Low pressure leak during ascent shorted out the 4x4 computer.
OBS5	LP108	T240-44	3.44	Drift: -0.019055
OBS6	LP103	T240-36	3.43	Drift: -0.038753

OBS data summary



Tom Bolmer, WHOI (OBS survey stations 1-18)



Tom Bolmer, WHOI (X = Surface drop location, Yellow = Final seafloor location)

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16. Abstract (Limit: 200 words)

The Ocean Bottom Seismometer Augmentation to the Philippine Sea Experiment (OBSAPS, April-May, 2011, R/V Revelle) addresses the coherence and depth dependence of deep-water ambient noise and signals. During the 2004 NPAL Experiment in the North Pacific Ocean, in addition to predicted ocean acoustic arrivals and deep shadow zone arrivals, we observed "deep seafloor arrivals" that were dominant on the seafloor Ocean Bottom Seismometer (OBS) (at about 5000m depth) but were absent or very weak on the Distributed Vertical Line Array (DVLA) (above 4250m depth). These "deep seafloor arrivals" (DSFA) are a new class of arrivals in ocean acoustics possibly associated with seafloor interface waves. The OBSAPS cruise had three major research goals: a) identification and analysis of DSFAs occurring at short (1/2CZ) ranges in the 50 to 400Hz band, b) analysis of deep sea ambient noise in the band 0.03 to 80Hz, and c) analysis of the frequency dependence of BR and SRBR paths as a function of frequency. On OBSAPS we deployed a fifteen element VLA from 12 to 8 52m above the seafloor, four short-period OBSs and two long-period OBSs and carried out an 11.5 day transmission program using a J15-3 acoustic source.

17. Document Analysis a. Descriptors

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Marine Seismology

b. Identifiers/Open-Ended Terms

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